Three Economic Perspectives on Post - 2012 Global Climate Policy

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“*In the long history of humankind (and animal kind, too) those who learned to collaborate and improvise most effectively have prevailed.*”

CHARLES ROBERT DARWIN, 1809 - 1882

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Résumé

Cette thèse présente trois perspectives économiques pour faire avancer un accord climatique international pour la période post 2012. La première partie développe un système de notation pour évaluer treize propositions de politique climatique. Les notes sont fondées sur quatre critères qui sont l'efficacité environnementale, l'efficacité économique, l'équité et la faisabilité institutionnelle. Les notes sont analysées par deux méthodes statistiques complémentaires: l'analyse en composantes principales et l'analyse par regroupement. Il est démontré que plus une proposition comprend un nombre important d'instruments, et plus difficile sera sa mise en œuvre. Les propositions qui incluent un effort significatif pour les Etats-Unis tendent à échouer dans l'efficacité environnementale et la faisabilité institutionnelle. La deuxième partie définit des scénarios internationaux en matière de politique climatique pour l'après 2012 à partir d'une analyse statistique d'interviews réalisées auprès des parties prenantes aux négociations climatiques. Cette analyse réalisée à l'aide de l'analyse des correspondances multiples a permis de construire trois scénarios faisables de politique climatique globale. Un résultat important est que le type de cible choisi pour les Etats-Unis conditionne, en grande partie, le régime climatique de l'après 2012. La troisième partie analyse les incitations et les caractéristiques souhaitables des transferts financiers pour les activités de réduction des gaz à effet de serre dans les pays en voie de développement. Ces transferts doivent être individuellement rationnels, budgétairement équilibrés, et doivent éviter aux pays de jouer un rôle de "passager clandestin" et de faire de fausses déclarations par rapport aux coûts et bénéfices liés directement aux efforts de réduction. L'analyse est affinée par l'inclusion du rôle des pays pivots dans la politique climatique internationale. Il a été démontré qu'il faut arbitrer entre des transferts qui évitent les fausses déclarations et des transferts qui sont budgétairement équilibrés et individuellement rationnels.

Mots clés: *politique climatique internationale pour l'après 2012, évaluation quantitative, approche participative, systèmes de transferts*

Abstract

This thesis presents three economic perspectives to moving forward a global climate agreement for post-2012. The first part develops a grading system for assessing thirteen proposals for post-2012 climate policy. The grades are based on four criteria: environmental effectiveness, cost effectiveness, distributional considerations and institutional feasibility. The grades are analyzed using two complementary methods: principal component and cluster analysis. It is shown that the higher the number of policy instruments a proposal comprises, the more difficult might be its implementation. Proposals which include a meaningful effort by the U.S. tend to fail in environmental effectiveness and institutional feasibility. Three proposals out of thirteen may be considered as suitable candidates for post-2012 climate policy. The second part defines feasible global climate policy scenarios by means of a participatory approach. Stakeholders' views are classified into three scenarios for post-2012 climate policy. Further, three points obtain a wide consensus among stakeholders: (i) 2013 is the most likely starting point for the next climate agreement, (ii) flexibility mechanisms will most probably be pursued, and (iii) technology and financial transfers to developing countries are likely to be used as incentives for these countries to undertake a more meaningful climate policy. The type of target for the United States largely determined the type of scenario the stakeholders envisaged for the post-2012 climate regime. The third part analyzes the incentives and the desirable features of transfer schemes for financing mitigation activities in developing countries. These desirable features are individually rational, budget-balanced, anti-incentives for free-riding and misrepresentation. Two alternative transfer schemes are tested. The analysis is further refined by the inclusion of the role of pivotal countries in the global climate policy. It was shown that there is a trade-off between transfers which avoid misrepresentation of countries and transfers that are budget-balanced and individually rational.

keywords: *post-2012 global climate policy, quantitative assessment, participatory approach, transfer schemes*

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List of Abbreviations

BAU	Business as Usual Scenario, page 77
CBF	Coal Bridge to the Future - Energy Alternative, page 88
CDM	Clean Development Mechanism, page 13
CDT	Climate-wise Development Treaty, page 90
CER	Certified Emission Reductions, page 16
COP-15	Fifteenth Conference of the United Nations Framework Convention on Climate Change Parties, page 2
DCs	Developing Countries, page 1
EDC	Emerging Developing Countries, page 8
ETS	Emissions Trading Systems, page 16
GDP	Gross Domestic Product, page 34
GEF	Global Environmental Facility, page 55
GEM	Group of Emission Markets, page 90
GHG	Greenhouse Gas, page 1
IC	Incremental Costs, page 60
ICs	Industrialized Countries, page 17
IPCC	Intergovernmental Panel on Climate Change, page 1
IPR	Intellectual Property Rights, page 45
JI	Joint Implementation, page 16
MCA	Multiple Correspondence Analysis, page 4
MRV	Measurement, Reporting and Verification, page 52
NAMAs	Nationally Appropriate Mitigation Actions, page 2
NGOs	Non-Governmental Organizations, page 35
PCA	Principal Component Analysis, page 3
ppm	parts per million of carbon dioxide equivalents, page 15

RD&D	Research, Deployment and Diffusion of low-carbon technology, page 7
SPAD 7.0	Statistical Package for the Analysis of Data, page 8
TRIPS	WTO's Agreement on Trade Related Aspects of Intellectual Property Rights, page 47
UNFCCC	United Nations Framework Convention on Climate Change, page 1

Introduction

International political response to climate change began with the adoption of the United Nations Framework Convention on Climate Change (UNFCCC) in 1992. The UNFCCC entered into force on 21 March 1994, and currently (September 2010) it has 194 parties. In December 1997, in Kyoto, Japan, the first Protocol under the UNFCCC was signed. Based mainly on the historical responsibility for Greenhouse Gas (GHG) emissions, the protocol committed developed countries and countries in transition - known under the UNFCCC as Annex I parties[1] - to achieve GHG emission reduction targets. These countries agreed to reduce their overall emissions of six GHG by an average of 5.2% below 1990 levels between 2008-2012, with specific targets varying from country to country. The Kyoto protocol finally entered into force on 16 February 2005.

Although the adoption of the UNFCCC and the Kyoto protocol have been major steps towards tackling climate change, this may not be sufficient. For example, the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) indicates a number of caveats existing in the current global climate policy architecture. These caveats include, among others, the lack of explicit long-term goals, insufficiently stringent targets, a narrow geographic scope due to the fact that Developing Countries (DCs) - non Annex I parties under the UNFCCC - do not have binding targets and the withdrawal of the United States, and finally, the insufficient promotion of technology development and transfer (Gupta et al., 2007).

The period of commitments of the Kyoto Protocol ends in 2012. At the moment, the international community is negotiating the new architecture for the post-Kyoto period. The *Bali Action Plan* (UNFCCC, 2007) initiated a negotiation process to facilitate reaching a

[1] The list of Annex I countries under the UNFCCC is, with slightly changes, the same as that of the Annex B of the Kyoto protocol. In the literature both terms are used in the same way in order to refer to developed or industrialized countries.

decision on a post-Kyoto agreement by December 2009 in the Fifteenth Conference of the UNFCCC Parties (COP-15) to the UNFCCC. However, the outcome of the COP-15 was not the expected *Copenhagen Protocol* but the *Copenhagen Accord* which is more a political declaration instead of an international binding agreement.

Even so, the *Copenhagen Accord* moved forward the post-2012 climate change agenda in some points: (i) the recognition of the political objective to reduce global emissions in order to maintain the increase in global temperature at below 2 degrees Celsius; (ii) that developed countries will implement quantified economy-wide emission targets for 2020; (iii) that DCs will implement mitigation actions through Nationally Appropriate Mitigation Actions (NAMAs); and (iv) the establishment of the Copenhagen Green Climate Fund as an operating entity of the financial mechanism of the UNFCCC. However, this summit failed in stating individual mitigation targets for developed countries as under the Kyoto protocol and it was not accepted by all UNFCCC's signatory countries - only 114 out of 194 parties had joined the Copenhagen Accord by September 2010. Thus, additional effort will be needed by the international community to reach a post-2012 global climate agreement. Nevertheless, once such an agreement is reached , it will most likely take several years for its ratification and entry into force, in particular because of the slow processes of discussion and consensus (Dernbach, 2008). This thesis studies the different dimensions of the post-2012 global climate policy and it sheds some light on how to move forward the climate change negotiations in order to achieve such an agreement.

Plan of the thesis

This thesis has been carried out from May 2007 to September 2010 in the framework of two research projects: the European FP6 project Technology-Oriented Cooperation and Strategies in India and China: Reinforcing the EU Dialogue with Developing Countries on Climate Change Mitigation (TOCSIN); and the Swiss NCCR-Climate project "Mitigation, Adaptation, and Acceptance" (MIADAC). Both research projects have been undertaken under the auspices of the Research Group of Economics and Management of the Environment led by Professor Philippe Thalmann at the Swiss Federal Institute of Technology in Lausanne (EPFL).

A post-2012 agreement needs to achieve early and substantial reductions of GHG emissions and to provide an effective means to further reductions in the long-term. In the existing literature, a variety of alternative climate policy architectures have been proposed in response to the perceived design flaws of the current climate regime.[2] Two ways of achieving early and substantial reductions of GHG emissions in a post-2012 global climate policy are available: by enhancing the participation of DCs with mitigation activities, and by promoting technology development and transfer. The main objective of this thesis was the identification and evaluation of likely global climate policies which focus on technological issues and/or DCs participation in order to obtain relevant findings which may contribute to moving forward the post-2012 global climate policy. The research tasks were grouped into three stages which led to three scientific articles (i.e., chapters). All three papers have been published. The first two papers were published in peer-review scientific journals. The third one has been recently submitted to a peer-review journal and published as an NCCR-Climate working paper.

There are many critical reviews of possible post-2012 architectures. Nevertheless, these reviews are mainly descriptive and concentrate on qualitative policy assessments.[3] A frequent shortcoming of such studies is that they provide long assessment descriptions of proposals, which makes it difficult to identify their critical elements and relevant information. Thence, the principal contribution of **chapter one** was the development of a quantitative assessment to highlight the main features of global climate policies. This method helps better the identification of the strengths and weaknesses as well as the conflicting structural elements within global climate policies. This study is the first applying the Principal Component Analysis (PCA) framework to identify trade-offs within climate policies and cluster analysis to study the similarities among a group of climate proposals. Among the proposals analyzed, six are technology-oriented approaches and the remaining seven request a special participation of DCs.

[2] For an outlook of the most relevant proposals, see for instance, Gupta et al. (2007) and Aldy and Stavins (2008a).

[3] For qualitative policy assessments, see among others, Aldy et al. (2003b); Bodansky (2003); de Coninck et al. (2008).

Proposals often face trade-offs, such as balancing environmental and cost effectiveness, distributional considerations, and institutional feasibility. It is difficult for a single proposal to promote all dimensions simultaneously; enhancing one aspect can compromise the achievement of another. As a result, the implementation of these policy scenarios would be limited. Thus, the **second chapter** searches policy scenarios for the post-2012 global climate policy by involving stakeholders linked to the climate change discussions. The study of policy scenarios helps in better understanding outcomes in open-ended processes, such as climate-change negotiations. Therefore, based on the theory of policy scenarios (Alcamo and Henrichs, 2008), this chapter recommends possible options and expected outcomes of the post-2012 international climate agreement. With the exception of Böhringer and Löschel (2005), participatory approaches have not yet been fully exploited with the aim of defining climate policy scenarios for post-2012. This is the first study which applies the Multiple Correspondence Analysis (MCA) framework to identify climate policy scenarios.

The participation of DCs is undoubtedly a key element in the post-2012 global climate policy. Thus, the **third chapter** centers on a new mechanism to enhance the participation of DCs with mitigation activities, namely NAMAs - Annex I countries pay for mitigation activities in DCs. This chapter studies the transfer design and incentives for NAMAs. For the provision of a public good, the design of transfers has been essentially centered on schemes which help to reveal the true valuation that agents have on the public good (i.e., asymmetric information) (Clarke, 1971; Groves, 1973; d'Aspremont and Gérard-Varet, 1979). On the contrary, for the case of global climate policies, they have been mainly focused on equity issues (Rose et al., 1998) and on the curtailing of free-rider incentives (Nagashima, 2010). In the third chapter, the desirable features of a transfer scheme for NAMAs were defined: it is individually rational, i.e., agents are not worse-off when participating; it is budget-balanced, i.e., total transfers are not negative; and it has to limit free-riding and avoid asymmetric informational incentives. Such an integral analysis of transfer schemes has not yet been carried out for global climate policies. It is shown how these transfer schemes perform in respect to these desirable features. The main contributions of this study were: (i) NAMAs were analyzed as a global public good under a game theoretical framework; (ii) countries' behaviors such as misrepresentation and deviations from full cooperation (i.e., free-riding) were identified, (iii) transfers that may alleviate these problems were tested, and (iv) the role of pivotal countries in the global climate policy was studied.

Methodology

The first paper developed a quantitative method to analyze proposals for post-2012 climate policy. This method consisted of three steps: (i) a grading system, (ii) PCA, and (iii) cluster analysis.

First, the grading system was based on the performance of global climate policies with respect to four criteria: (i) environmental effectiveness, (ii) cost effectiveness, (iii) distributional considerations, and (iv) institutional feasibility. The grades served as an input for the PCA and the cluster analysis. Each of the four criteria had the same weight, and the proposals were graded according to each criterion using four levels of attainment (employing an equidistant scale): very good performance (grade=1), good performance (grade=3/4), medium performance (grade=1/2), and poor performance (grade=1/4).

Environmental effectiveness was considered as the extent to which a climate policy meets its intended environmental objectives; i.e., certainty of GHG emission reduction level. Cost effectiveness was considered as the extent to which a policy achieves its objectives at minimum cost to society. Thus, emission reductions occur in whichever sector or country they are least costly. A meaningful global climate policy should include flexibility mechanisms to allow countries with high marginal abatement costs to pay for reductions in countries with low marginal abatement costs. Distributional considerations refer to the incidence of a policy on dimensions such as fairness and equity. These issues are some of the most politically charged in international negotiations. The assessment of international, intra-national, and intergenerational distributions of the benefits and costs of alternative policy regimes is necessary for the identification of equitable climate strategies. In this respect, a feasible global climate policy may include burden sharing and participation rules considered as fair for the set of participating countries. Institutional feasibility is the extent to which a policy instrument is likely to be viewed as legitimate, to gain acceptance, and to be adopted and implemented. Principally, two aspects of institutional feasibility are critical in reaching a successful global climate agreement: (i) negotiation and adoption of an agreement and (ii) its subsequent implementation.

Second, the system of grades for assessing global climate policy options described above was used to obtain a quantitative data set to perform a PCA. The PCA compared at the same time the proposals under a single criterion and the criteria for a single proposal. The PCA was performed using the software package R, which is an open source application of the S-Plus language (see Everitt and Hothorn (2006)).

Third, for the cluster analysis, the *K-means* method was used. The general algorithm followed in order to perform the cluster analysis consisted of: (i) finding a clustering criterion; in this case the *elbow* criterion was chosen as described by Everitt and Hothorn (2006) for the *R package*, where they look for an *elbow* by plotting the within-group of squares against the number of groups. The *elbow* is the number of clusters at the point where the curve shows the strongest angle in the graph. (ii) Determining the group memberships. (iii) Repeating step *ii* until finding a stable partition (i.e. the same proposals by cluster). The cluster analysis randomly produces, for each *elbow* found, clusters with a different combination of proposals. This partitioning is repeated until the same membership by clusters is obtained. Then, these clusters are considered as stable.

The second paper followed a participatory approach to construct climate policy scenarios for the post-2012 world. Stakeholders participated in two steps: First, a stakeholders group defined the architectural complexity of the climate-change negotiation process and the possible outcomes of this process (global climate policies) by taking part in a questionnaire-interview. Second, a broader stakeholder group assessed the feasibility of the possible outcomes defined by the first stakeholder group in responding to another survey-questionnaire. An MCA of the answers of the second stakeholder group was performed.

The design of the questionnaires followed the four standard steps for this type of study, used in sociology, as described by Grawitz (2000). After identifying the stakeholders involved in the climate change negotiation process, an interview-questionnaire was developed with the aim of exploring the architectural complexity of the climate change negotiation process and the possible outcomes (global climate policy). This questionnaire was designed to interview stakeholders face-to-face. Questions were grouped into six general topics: (i) the feasibility of a short-term GHG emission reduction target and a long-term stabilization goal, and the timetables for these objectives; (ii) flexibility provisions designed to lower the cost of implementing a global climate policy; (iii) burden-sharing rules for mitigation and adaptation efforts, as well as for financing the cost of impact to climate change; (iv) how the Research, Deployment and Diffusion of low-carbon technology (RD&D) will be introduced into a post-2012 climate policy; (v) measures to encourage the United States and DCs to play a more active role in climate-change issues; (vi) the stakeholder's personal considerations concerning a post-2012 climate policy scenario.

The interview answers were analyzed in four stages: (i) transcription of the recorded interviews; (ii) verification and interpretation of each interview to establish the intended correlations; (iii) grouping of questions; and (iv) codification. Furthermore, it was considered that for closed questions there were two possible answer categories (yes and no), whereas answers to open questions were classified by common points and similarities (e.g., tendency or affinity). Drawing on the results from the interviews in the first step of this study, the main beliefs of the interviewees concerning the features of viable global climate policies for the post-2012 period were highlighted. In order to assess the feasibility of the different climate policy elements identified, a new questionnaire was created, which was sent to a larger number of stakeholders. The survey-questionnaire was, in principle, an adaptation of the interview-questionnaire. Nevertheless, in the new questionnaire, some of the initial beliefs were corrected.

The survey-questionnaire contained closed questions with the answer alternatives (response categories) proposed by the stakeholders interviewed in the first part of this study. However, each question also offered a blank answer option - free to be filled out by the respondent - and some questions were better formulated as a result of lessons learned from the first questionnaire. The closed questions were grouped around: the kind of targets for Annex B countries, the United States and Emerging Developing Countries (EDC); incentives for the U.S., and EDC participation; elements for technology development and sharing of low-carbon technologies; the kind of flexibility mechanisms to be included; adaptation concerns; and the viable global target for 2030. There were four open questions regarding the respondents' personal views on the most controversial issues in the ongoing negotiation process and the ideal solutions for these issues, as well as the most likely starting date for the next commitment period and its duration (in years).

With the aim of finding answer patterns in the survey-questionnaire, an MCA was performed. The main steps followed during the MCA analysis were: First, the transformation of the survey-questionnaire into a *Standard Format*. Second, performing the MCA as described by Greenacre (1993). Third, the MCA tool in the Statistical Package for the Analysis of Data (SPAD 7.0) was employed to perform the MCA analysis. For the MCA, only the response categories represented between a range of 10% and 90% were employed. Categories with a representation greater than 90% (more than 100 stakeholders) were considered a consensus. Finally, the statistical quality of the variables was verified, because only significant categories may be represented. Significant active categories were those whose contribution to one of the axes was greater than the average contribution to one axis (Rouanet, 2006). The average contribution was 1.89 for each axis. Significant supplementary categories were those with absolute test value greater than 2, which indicates a significant position of the corresponding category in respect to the axes (Lebart et al., 2006).

The third paper pursued a game-theoretical approach to study the transfer design and incentives for the participation of countries in a new international instrument under the UNFCCC, namely NAMAs. Countries negotiate NAMAs in a non-cooperative way - i.e., countries make decisions independently and any cooperation must be self-enforcing. In NAMAs, Annex I countries finance mitigation activities in DCs. NAMAs has the character of a global public good. The good is the damages avoided by reducing GHG emissions (i.e., environmental gain) and no country is excluded from the benefits obtained by these reductions. However, these costs and benefits vary depending on the country's characteristics. A country with higher mitigation costs than the benefits it perceives from NAMAs receives a monetary transfer; otherwise it contributes with the financing of NAMAs programs abroad.

The model was based on three primary conditions. Firstly, a necessary requisite for the implementation of NAMAs is that the total environmental gain equals or exceeds total costs (feasibility condition). Secondly, cooperation must be *individually rational* as final payoff of every country is non-negative. Thirdly, it was assumed that there was no source of funds (beyond countries' transfers) to finance NAMAs as total transfers are not negative. In other words, total transfer covers total cost. In addition, the model considered the existence of pivotal countries for the implementation of NAMAs - the global public good is not provided if they do not participate in NAMAs. Furthermore, the model analyzed countries' behavior and deviations from full cooperation such as free-rider incentives and asymmetric informational problems.

Finally, NAMAs was analyzed under two transfer schemes, namely the *horizontal equity-based* transfer scheme and an "optimal" transfer scheme *à la Weikard*. Under the *horizontal equity-based* transfer scheme every country receives the same final payoff from the reduction of GHG emissions; and under the "optimal" transfer scheme *à la Weikard*, a country's final payoff is, at least as much as that which it could have received by free-riding, namely the outside option payoff.

The following three chapters contain the scientific articles just summarized above. They are followed by a general conclusion that synthesizes the major findings of this research as well as an outlook on further research and some implications for policymaking.

Chapter 1

Trade-offs and performances of a range of alternative global climate architectures for post-2012

This chapter is a modified version of Ronal Gainza-Carmenates, Juan Carlos Altamirano-Cabrera, Philippe Thalmann and Laurent Drouet (2010), "Trade-offs and performances of a range of alternative global climate architectures for post-2012", Environmental Science and Policy, 13, 63-71.

Abstract

Quantitative assessments help to highlight the main features of climate policies by better identifying their strengths and weaknesses. In this study, we develop a grading system for assessing thirteen proposals for post-2012 climate policy. We believe that these proposals contain appropriate policy instruments which will be considered for discussions about how to design the post-2012 climate agreement. Our grades are based on four criteria: environmental effectiveness, cost effectiveness, distributional considerations and institutional feasibility. We analyze the grades with two complementary methods: principal component and cluster analysis. Our results entail three policy implications. Firstly, the higher the number of policy instruments a proposal comprises, the more difficult might be its implementation. Secondly, proposals which include a meaningful effort by the U.S. tend to fail in environmental effectiveness and institutional feasibility. Thirdly, we identify that the "first best" and the "second best" approaches belong to a stable policy group, and both may be considered as suitable candidates for post-2012 climate policy.

Keywords: *post-2012 global climate architecture, principal component analysis, cluster analysis*

1.1 Introduction

A post-2012 agreement needs to achieve early and substantial reductions of GHG emissions and to provide an effective means of further reductions in the long-term. In the existing literature, a variety of alternative climate policy architectures have been proposed in response to the perceived design flaws of the current climate regime.[1] These alternatives are focused on the following themes: (i) national emission targets and emission trading, (ii) sectoral approaches, (iii) policies and measures, (iv) technology, (v) development-oriented actions, (vi) adaptation, (vii) financing, and (viii) negotiation process and treaty structure (Gupta et al., 2007). This paper focuses on policies designed to respond to two of the caveats mentioned above, namely: low participation of DCs and the insufficient promotion of technology development and transfer. We consider that these two issues are the most critical elements in overcoming the current gridlock in climate change negotiations and in achieving a new climate agreement for the next commitment period.

There are many critical reviews of possible post-2012 architectures. These reviews are mainly descriptive and concentrate on qualitative policy assessments.[2] A frequent shortcoming of qualitative assessments is that they provide long assessment descriptions of proposals, which makes it difficult to identify their critical elements and relevant information. We think that a quantitative assessment helps to highlight the main features of climate policies by better identifying their strengths and weaknesses. Therefore, the main objective of this paper is to identify policy performances and conflicting structural elements of thirteen global climate architectures by employing a quantitative framework based on the use of four criteria. Among the global climate policy architectures that we analyze, six are technology-oriented approaches and the remaining seven request a special participation of DCs.

A previous quantitative study was carried out by Kuik et al. (2008). They classified forty-four proposals along five policy choices based on a 5-point scale that includes two extreme responses. These policy choices are: (i) incentive structure (to punish or to reward good

[1] See, for instance, Gupta et al. (2007) and Aldy and Stavins (2008a).

[2] See, among others, Aldy et al. (2003b); Bodansky (2003); de Coninck et al. (2008)

behavior); (ii) reducing GHG through either a climate policy alone or as a side benefit of other policies; (iii) focused on market solutions or direct regulations; (iv) based on multilateral solutions or small-party agreements; and (v) focused on mitigation or adaptation activities. Kuik et al. (2008) conclude from the grading that many proposals share the following features: (i) they have some ideas on how to reduce emissions, (ii) they formulate climate policy in isolation, and (iii) they advocate market-based solutions. Furthermore, most proposals have a preference for a UN-based regime. We consider that this assessment has two major shortcomings. Firstly, it does not describe explicitly the proposal elements responsible for their performance under the five policy choices. Secondly, the grading given to proposals is not exploited further. For instance, it could be used to show which proposal performs best under these choices, or to explore why proposals perform better for some policy choices than for others. In this study, we develop a grading system to assess the global climate policies based on four "classical" criteria: (i) environmental effectiveness, (ii) cost effectiveness, (iii) distributional considerations, and (iv) institutional feasibility. We improve the analysis of Kuik et al. (2008) in two respects. Firstly, we define clearly the system of grading employed to transform the qualitative information into quantitative data. Secondly, we extend the analysis by employing two statistical methods: PCA and cluster analysis.

PCA helps us to characterize the performance of the proposals studied by emphasizing their main features on the basis of the four criteria, and at the same time it allows us to determine "conflicting situations", if any, among the criteria. Cluster analysis is performed with the purpose of finding relationships among the proposals with the best performance levels. To the best of our knowledge, the combination of these two statistical methods has not been applied before to the analysis of climate policies. This is the first paper which applies the PCA framework to identify trade-offs within climate policies. Cluster analysis has been used in related fields such as environmental management by Buysse and Verbeke (2003) and to classify DCs according to their attractiveness for Clean Development Mechanism (CDM) projects by Jung (2006). However, this has not yet been applied to study the similarities among a group of climate proposals.

The remainder of this chapter is organized as follows: Section 1.2 describes the methodological framework which consists of three interconnected components - the grading system for assessing global climate policy options, PCA method and the cluster analysis; Section 1.3 presents the thirteen proposals; Section 1.4 discusses the major results from our analysis and Section 1.5 concludes.

1.2 Methodology

Qualitative assessments of climate policies, by providing long descriptions of them, make it difficult to identify their most critical elements. In order to overcome this limitation, we develop, in this paper, a quantitative method to analyze proposals for post-2012 climate policy. Our method consists of three steps: (i) a grading system, (ii) PCA, and (iii) cluster analysis. The grading system is based on the performance of global climate policies with respect to four criteria: (i) environmental effectiveness, (ii) cost effectiveness, (iii) distributional considerations, and (iv) institutional feasibility. The grades serve as an input for the PCA and the cluster analysis. PCA helps to characterize the performance of the thirteen global post-2012 proposals studied, by emphasizing their main features on the basis of the four criteria, and at the same time allows us to determine "conflicting situations", if any, among the criteria. Cluster analysis is performed with the intention of finding relationships among the proposals (by grouping them). In the following, we describe these three steps.

1.2.1 Grading system to assess the performance of global climate policies

Several authors have proposed different criteria that can guide an assessment of global climate policy architectures (see among others, Aldy et al. (2003b) and Bodansky (2003)). In this paper, we use the four criteria for evaluating environmental policy instruments proposed in the IPCC Working Group III Fourth Assessment Report (Gupta et al., 2007). These criteria are: (i) environmental effectiveness, (ii) cost effectiveness, (iii) distributional considerations, and (iv) institutional feasibility. For our analysis, we give the four criteria the same weight, and we grade the proposals according to each criterion using four levels of attainment (employing an equidistant scale): very good performance (grade=1), good performance (grade=3/4), medium performance (grade=1/2), and poor performance (grade=1/4). In the following, we describe the main elements that guide our grading system.

- Environmental effectiveness

Environmental effectiveness is considered, in this paper, as the extent to which a climate policy meets its intended environmental objectives; in our case, certainty on GHG emission reduction level. However, securing global reduction of GHG emissions is not enough. The target of any meaningful global climate policy would be to reach the ultimate objective of the UNFCCC, which is to achieve the stabilization of GHG concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system (UNFCCC, 1992). The fourth assessment report of the IPCC (Barker et al., 2007) considers long-term stabilization targets between 445 and 1130 parts per million of carbon dioxide equivalents (ppm) CO_2 eq. The lower the stabilization level, the faster GHG emissions have to peak and decline.

In this study, as it has been pointed out in many other studies (e.g. Edmonds and Sands (2003), Murphy et al. (2004) and Barker et al. (2007)), we consider that a reasonable and appropriate environmental objective is to achieve stabilization at a maximum of 550 ppm CO_2 eq., thereafter 550 ppm, between 2100 and 2150. Edmonds and Sands (2003) state that a 550 ppm target could be agreed as an *indicative* concentration target, as there is an increasing consensus that costs of reaching the 550 ppm target are much lower than of reaching 450 ppm. In this direction, Murphy et al. (2004) suggest that 550 ppm is associated with the lowest probability of exceeding 4°C, a level at which it is projected that significant and irreversible changes in the world occur. Barker et al. (2007), based on several studies, argue that a likely point in time for stabilization is generally between 2100 and 2150. Furthermore, we grade the environmental effectiveness of the proposals following the performance of different policy instruments described by Bodansky (2003).

With these references, proposals based on policy instruments and measures that hardly reduce GHG emissions are graded with *poor performance*. Approaches show *medium performance* when policy measures, goals and targets reduce GHG emissions to some extent but a long-term stabilization target is missing, and/or they do not avoid emissions leakage, and/or the expected policy outcome is uncertain since it depends on how stringent the possible commitment is. Those architectures which propose policy instruments, goals and targets that should attain strong GHG reductions, but still have some design flaws which may jeopardize effective GHG reductions such as an insufficient stabilization target, are considered to have *good performance*. Finally, we assign *very good performance* to proposals which seek to stabilize GHG concentration in the atmosphere at the most at 550 ppm by 2150 at the latest and which contain instruments that enable attaining this objective.

- Cost effectiveness

We consider cost effectiveness as the extent to which a policy achieves its objectives at minimum cost to society. Thus, emission reductions occur in whichever sector or country they are least costly. A meaningful global climate policy should include flexibility mechanisms to allow countries with high marginal abatement costs to pay for reductions in countries with low marginal abatement costs. This can be achieved, for instance, through market-based approaches such as Emissions Trading Systems (ETS), taxes, Joint Implementation (JI) and CDM projects. The more flexibility for countries, the greater the cost effectiveness (Aldy et al., 2003b).

To grade the proposals for cost effectiveness, we have considered the evaluations done by Aldy et al. (2003a) and Aldy and Stavins (2008b). With these references, we grade with *poor performance* proposals based only on RD&D and/or technology standards, and/or sectoral or country targets, and those that do not propose a clear flexibility mechanism to lower GHG reduction costs. Proposals based on technology policies, especially those too directive about the technologies to promote and which help to reduce transaction costs are considered to have *medium performance*. We consider policies with *good performance* if they allow markets to work well, and/or are shaped to countries' circumstances, and/or consider some flexibility mechanisms to lower compliance costs (i.e. Certified Emission Reductions (CER), CDM, JI and ETS), and/or are based on flexible reductions targets (i.e. indexed targets, absolute targets with safety valve); but the policy design has still some no-table flaws that should lead to some noticeable economic inefficiency (i.e. it fails to equalize marginal costs or comprise high transaction costs), or implementation cost uncertainties. Finally, policies which do not present any of the economic inefficiency mentioned above (for the good performance grade) are considered to have *very good performance* for this criterion.

- Distributional considerations

Distributional considerations refer to the incidence of a policy on dimensions such as fairness and equity. These issues are some of the most politically charged in international negotiations. The assessment of international, intra-national, and intergenerational distributions of the benefits and costs of alternative policy regimes is necessary for the identification of equitable climate strategies. In this respect, a feasible global climate policy may include burden sharing and participation rules considered as fair for the set of participating countries.

The graduation of the proposals considering distributional effects is based on the set of tools discussed by Ashton and Wang (2005).[3] They expose five conditions that a new global climate agreement must meet in order to be robust across the key equity dimensions: (i) meaningful efforts to reduce emissions by the U.S. (either binding or non-binding), (ii) a continued leadership by Industrialized Countries (ICs), (iii) some DCs reducing their emissions (under binding or not binding commitments), (iv) more help to DCs in dealing with climate impacts and adaptation issues and (v) other kinds of help to DCs in order to deal with other concerns than climate change. Therefore, we grade an approach which does not consider any of Ashton and Wang's conditions with *poor performance*. A policy that meets at most two of Ashton and Wang's conditions is qualified as *medium performance*. Those proposals meeting three or four conditions receive a grade of *good performance*. Finally, policies which consider the five conditions are graded as having *very good performance*.

[3] For further details on alternative equity principles see Rose et al. (1998).

- Institutional feasibility

Institutional feasibility is the extent to which a policy instrument is likely to be viewed as legitimate, to gain acceptance, and to be adopted and implemented. Mainly, two aspects of institutional feasibility are critical in reaching a successful global climate agreement: (i) negotiation and adoption of an agreement and (ii) its subsequent implementation. Bodansky (2003) explains that for a global climate agreement to be effective over the long-term, the commitments need to take into account the capabilities and limitations of the institutions on which implementation and compliance depend.

Following Bodansky (2003), we consider proposals to have *poor performance*, if negotiations at the current time would be too difficult and long, and/or they require new international institutions or frameworks, or they do not have acceptance by major international players. Approaches in line with the current climate regime and that include some elements with an attractive result, or that gain in acceptance by major international players apart from the U.S., are graded as having *medium performance*. *Good performance* is for approaches which, in addition to being compatible with the current climate regime, would offer an attractive outcome for all major players (i.e. Annex B countries of the Kyoto protocol, the U.S., and EDC). However, they still contain some elements which would to some extent make their negotiation difficult (i.e. significant reforms of current mechanisms). Finally, a *very good performance* for this criterion is given to an architecture totally compatible with the current international climate regime and other international frameworks and institutions; in addition, the agreement would be easy to implement and it would be accepted by, at least, all major international players.

1.2.2 PCA Method

The basic aim of the PCA is to describe the variation in a set of correlated variables (in our case, the four criteria), in terms of a new set of uncorrelated variables (the principal components), each of which is a linear combination of the original variables. These new variables are derived in decreasing order of importance in the sense that the first component accounts for most of the variation in the original data amongst all linear combinations of the original variable. Then, the second principal component is chosen to account for as much as possible of the remaining variation, subject to being uncorrelated with the first principal component, and so on. The system of grades for assessing global climate policy options described in the former Section (a scale from 0.25 to 1 relative to their performance on each criterion) allows us to obtain a quantitative data set to perform the PCA. PCA allows us to compare at the same time the proposals under a single criterion and the criteria for a single proposal. We perform the PCA using the software package R, which is an open source application of the S-Plus language (see Everitt and Hothorn (2006)).

1.2.3 Cluster Analysis Method

Cluster analysis is used to examine multivariate data with a view to discover groups or clusters of observations that are homogeneous and separated from other groups.[4] In this paper, we use the *K-means* method which belongs to the partitioning cluster methods that sort the individuals (in our case proposals) in a series of interactions until converging to a stable partition of *K* clusters. Our choice is based on the fact that the *K-means* clustering technique seeks to partition a set of observations into a specified number of groups by maximizing their main features, i.e. the *K-means* method will group the proposals which share high performance levels (i.e. good or very good) for criteria instead of considering the lower values (i.e. poor performance).

The comparison of cases in the *K-means* method is based on the square Euclidean distance of the cases to the cluster centers. The general algorithm followed to perform the cluster analysis consists of: (i) finding a clustering criterion; in our case we choose the *elbow* criterion described by Everitt and Hothorn (2006) for the *R package*, where they look for an *elbow* by plotting the within-group of squares against the number of groups. This method is a slight variation of the traditional method which plots the percentage of variance explained by the clusters against the number of clusters. In both cases the *elbow* is the number of clusters at the point where the curve shows the strongest angle in the graph. (ii) Determining the group memberships. (iii) Repeating step *ii* until finding a stable

[4] Detailed clustering techniques are described in Everitt et al. (2001).

partition (i.e. the same proposals by cluster). The cluster analysis randomly produces, for each *elbow* found, clusters with different combination of proposals. This partitioning is repeated until the same membership by clusters is obtained. Then, these clusters are considered as stable.

1.3 Thirteen proposals for post-2012 climate policy architecture

1.3.1 Technology-oriented proposals

The potential role of international technology-oriented agreements for post-2012 climate policy has gained relevance over the last decade. Several international technology coordination programs have been launched, including the Generation IV International Forum on nuclear power, the International Partnership for the Hydrogen Economy, the Methane to Markets Partnership, the Carbon Sequestration Leadership Forum and the Asia-Pacific Partnership on Clean Development and Climate. These programs have benefited from the support of the United States and some of the more rapidly growing DCs.

Technological innovation is undeniably important for stabilizing GHG concentrations in the atmosphere. International technology cooperation, by sharing information, costs, and efforts, might accelerate and facilitate the transition to more climate-friendly technologies (Philibert, 2003). In addition, RD&D efforts, effective policies, regulations, market deployment strategies and economic tools need to be part of a climate agreement in order to make it effective (Justus and Philibert, 2005).

Goulder (2004) argues that a variety of climate policies can spur additional or "induced" technological change and lower the cost of achieving GHG reductions. This can be achieved through technology "push" policies that boost the invention and innovation processes, and through *direct emissions* policies that "pull" new technologies into the market. Goulder (2004) also concludes that in order to reduce GHG emissions cost-effectively, both technology-push and *direct emissions* policies are required.

In this study, we decided to analyze six approaches that cover, in our opinion, the major aspects described for technology issues to this date. They are (i) the *Technology Backstop*

Protocol (Edmonds and Wise, 1998), (ii) the *Portfolio* approach (Benedick, 2001), (iii) the *Research and Development* approach (Barrett, 2003), (iv) the *International agreements on energy efficiency* approach (Ninomiya, 2003), (v) the *Technology prizes* approach (Newell and Wilson, 2005), and the (vi) *Orchestra of Treaties* approach (Sugiyama and Sinton, 2005). In the appendix A.1, we describe the most relevant characteristics of these proposals.[5]

1.3.2 Proposals for DCs participation

DCs have no binding commitments under the current international climate regime but may host emission reduction projects through the CDM. Nevertheless, reaching the stabilization of GHG concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system will only be possible if emission reductions are intensified and participation in those reductions is broadened (Dernbach, 2008). Therefore, many approaches for the post-2012 period focus on finding mechanisms to achieve a more important participation of DCs.

In this study, we decided to analyze seven approaches that cover, in our opinion, the most interesting mechanisms described in this area to this date for DCs participation, such as multi-commitment approaches either binding or non-binding, graduation mechanisms using different criteria, voluntary or binding agreements for major economies or major emitters, mitigation actions in DCs supported by ICs, and staged system approaches. These approaches are: (i) the *Multi-dimensional structure* approach (METI, 2003), (ii) the *Bottom-up* approach (Reinstein, 2004), (iii) the *Common but differentiated convergence* approach (Höhne et al., 2006), (iv) the *Formulas for emission targets* approach (Frankel, 2007), (v) the *Graduation and deepening* approach (Michaelowa, 2007), (vi) the *Pledge-and-review* approach (Pizer, 2007) and (vii) the *Three-part policy architecture* (Stavins, 2004). In appendix A.2, we describe the most relevant characteristics of these proposals.

[5]There is an overlap of the technology-oriented proposals included in table 13.2 of IPCC Working Group III (Gupta et al., 2007) of the fourth assessment report with the proposal that we have analyzed. However, we did not use this table as a criterion to choose the proposals. As it can be seen, in addition to the four technology-oriented approaches included in such a table, we include in our study two other proposals: (i) the *Orchestra of Treaties* (Sugiyama and Sinton, 2005) and the *Portfolio* approach (Benedick, 2001).

1.4 Results and discussion

1.4.1 Proposal performance

We apply our grading system (see Section 1.2.1) to the thirteen proposals listed in Section 1.3 with the aim of assessing their performance under four criteria (see table 1.1). In table A.1 of the appendix A.3, we present the main elements of each proposal that back the grade they attain from our grading. We obtain two main findings. Firstly, we observe that there are no proposals with very good performance for all criteria considered. Only one proposal, the *Three-part policy* (Stavins, 2004), attains very good scores for three criteria. It is only under distributional considerations that this proposal obtains only a good grade since Stavins (2004) proposes neither meaningful U.S. participation nor additional assistance to DCs to tackle issues other than climate change. In the end, the *Three-part policy* is definitely the best approach, out of the thirteen, to be considered for post-2012 climate policy. We call it, the "first best" option.

Secondly, table 1.1 allows us to identify that there are two other proposals which obtain an evaluation of good or very good performance for the four criteria: the *International agreements on energy efficiency* (Ninomiya, 2003) and *Graduation and deepening* (Michaelowa, 2007). Consequently, among the remaining twelve proposals which we study, we may propose these two approaches as the "second best" options for post-2012 climate policy. We may expect that if an eventual negotiation and subsequent implementation based on the first best approach faces any unexpected contingency, in practical terms, these two approaches may be taken into consideration by policy makers as second options for post-2012 climate policy.

Our findings raise two main concerns. The first one is the fact that no architecture fulfils the four criteria with a very good score. This suggests that there may exist "rival" structural elements within them. The second is that it remains still unclear to what extent the "second best" approaches would resemble the "first best" approach. The information from table A.1 of appendix A.3 is not enough to clarify these two matters. Hence, we appeal for the use of two supplementary methods: the PCA and the cluster analysis. We perform a PCA with the aim of better identifying such internal "rival" structural elements, and we carry out a cluster analysis in order to search the level of policy resemblance, in terms of overall performance, between the "first best" and the "second best" approaches.

Table 1.1: Degree of performance of the thirteen global climate policy architectures to the criteria

Proposal[a]	Environmental effectiveness	Cost effectiveness	Distributional considerations	Institutional feasibility
A) Technology backstop protocol (Edmonds and Wise, 1998)	very good	poor	medium	good
B) Portfolio approach (Benedick, 2001)	medium	good	good	poor
C) Research and development approach (Barret, 2003)	medium	poor	good	good
D) International agreements on energy efficiency (Ninomiya, 2003)	good	very good	good	very good
E) Technology prizes (Newell and Wilson, 2005)	poor	medium	n/a	very good
F) Orchestra of Treaties (Sugiyama and Sinton, 2005)	medium	good	very good	poor
G) Multi-dimensional structure (METI, 2003)	medium	good	very good	good
H) Bottom-up approach (Reinstein, 2004)	good	very good	good	poor
I) Common but differentiated convergence (Höhne, 2006)	very good	good	very good	medium
J) Formulas for emission targets (Frankel, 2007)	good	very good	good	medium
K) Graduation and deepening (Michaelowa, 2007)	very good	very good	good	good
L) Pledge-and-review approach (Pizer, 2007)	medium	good	good	poor
M) Three-part policy architecture (Stavins, 2004)	very good	very good	good	very good

[a] The grades associated to our analysis are: very good performance = 1, good performance = $3/4$, medium performance = $1/2$, poor performance= $1/4$ and not applicable = 0.

1.4.2 PCA

By processing the scores attained by the proposals, PCA helps to find patterns and tendencies among the proposals with respect to the four criteria. PCA enables us to focus on the main characteristics of the proposals by highlighting their strengths and weaknesses. Eigenvalues give an idea about the integrated performance of proposals under the four criteria while simultaneously considering the performance of the other proposals. For example, figure 1.1 shows the position depicted by the proposals when facing the four criteria based on the eigenvalues computed by the first principal component. Here, the institutional feasibility criterion attains a value of $+0.11$ whereas cost effectiveness gets -0.70. The difference in signs means that they are negatively correlated, and the level gives an indication of the relative distance between them.

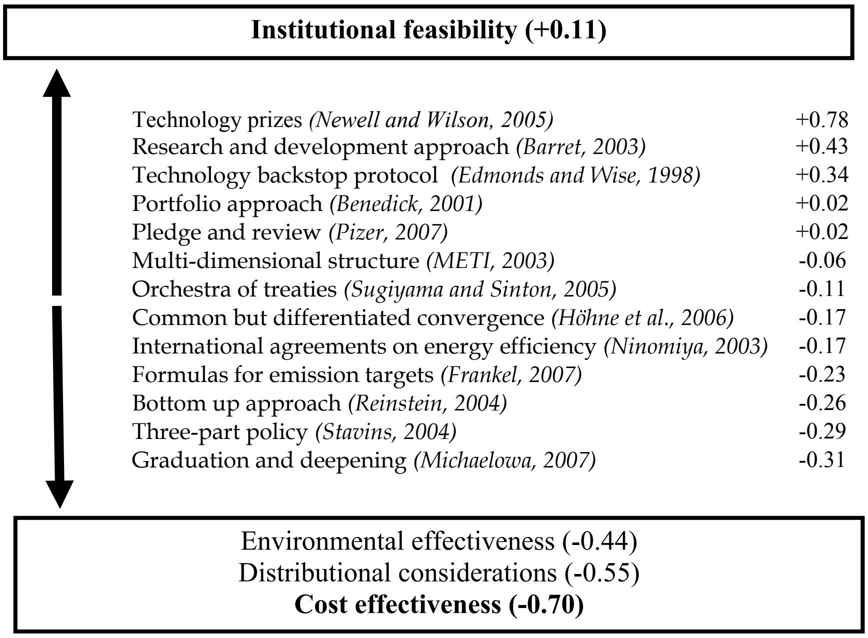

Figure 1.1: Position of the climate policy architectures relative to the four criteria organized in the first principal component.

In our study, we find that the two first principal components (variables) explain together 73.5% of the variance. The first principal component (which explains 39.0 % of the variance) suggests that the better a proposal performs on environmental effectiveness, distributional considerations and cost effectiveness, the less feasible it might be and vice versa. In our view, this opposition is due to the fact that those architectures which propose a large quantity of instruments in order to answer these three dimensions properly, and even issues other than climate, tend to be less feasible. This finding is important for designing climate policies since it suggests that the higher the number of policy instruments a proposal comprises, the more difficult might be its implementation - e.g. due to lengthy negotiations or new negotiation frameworks. As Kok and de Coninck (2007) state, widening climate change policy by strengthening inter-linkages between climate policies and other relevant policy areas, such as development policy, requires strong political will and active follow-up in implementation, issues that are still missing from the current institutions.

To illustrate our point, let us take as an example the most outstanding proposals in the first principal component: the *Graduation and deepening* and the *Technology prizes* approaches. The first (at the bottom of figure 1.1) performs very good for environmental and cost effectiveness. It proposes to include in a future climate agreement new sectors, a new GHG basket, and a new mechanism for DCs participation, among other instruments. However, the negotiation process on all these new elements may take a long time before achieving a concrete agreement, if any. In contrast, the implementation of prizes to spur climate change-related technological advances, proposed under the *Technology prizes* approach (at the top of figure 1.1), is characterized by very good feasibility, but it does not include enough elements to design an effective, efficient and equitable global climate architecture.

The second principal component, which explains a further 34.5 % of the variance, opposes mainly institutional feasibility and environmental effectiveness to distributional considerations, with the strongest opposition between institutional feasibility and distributional considerations - see figure 1.2.[6] This result may turn out to be very important when designing global climate policies since it means that we may not obtain more equitable policies without worsening their feasibility and environmental performance. This result suggests that behind the five conditions of Ashton and Wang for distributional considerations there may be hidden "unfeasible" elements and it would be necessary to link them with some highly flexible policy instruments. However, the implementation of such policy packages consequently reduces the performance of the proposal regarding its environmental effectiveness.

Analyzing jointly the position of the proposals along the second principal component, their policy instruments, and their performance attained for the criteria (see details in the

[6] In the second principal component, the eigenvalue of cost effectiveness is equal to zero. This means that the distribution of the proposals on the second principal component is not affected by this criterion.

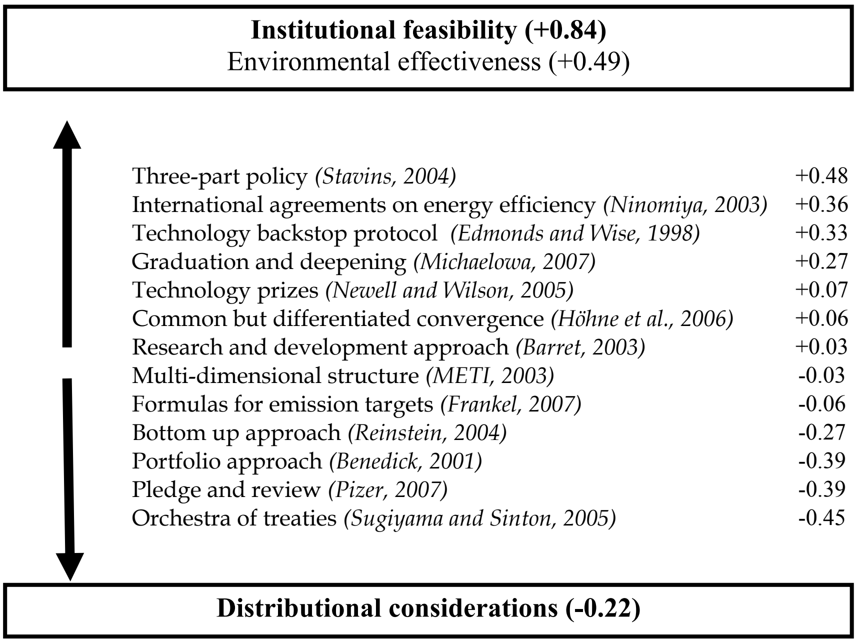

Figure 1.2: Position of the climate policy architectures relative to the four criteria organized in the second principal component.

table A.1 of appendix A.3), we find that the conflicting condition is the meaningful effort of the U.S. in the post-2012 period. This conflicting condition is evident when we look closely at the approaches which oppose the most along the second principal component: the *Orchestra of Treaties* and the *Three-part policy*. On the one hand, the first (at the bottom of figure 1.2) meets all the conditions of Ashton and Wang. Nevertheless, it shows a medium performance under environmental effectiveness and a poor performance under institutional feasibility. This is due to the fact that this proposal suggests that the U.S. should take the leadership in the implementation of a Group of Emission Markets. In order to reach such U.S. involvement, the *Orchestra of Treaties* proposes to base GHG emission reductions only on the implementation of such emission markets, which does not ensure the needed environmental outcome of a post-2012 architecture. Furthermore, it proposes to negotiate their main elements of the treaty outside of the UNFCCC system, for instance, in the Group of Eight where the U.S. may have a significant influence in the decisions. On the other hand, the *Three-part policy* (at the top of figure 1.2) does not ask for meaningful U.S. participation, and it shows very good performance for environmental effectiveness and institutional feasibility.

1.4.3 Cluster analysis

After identifying the "rival" properties in the climate architectures studied, we perform a cluster analysis in order to find the degree of policy resemblance, in terms of overall performance, between the "first best" solution (the *Three-part policy*) and the "second best" approaches (the *International agreements on energy efficiency* and *Graduation and deepening*). This analysis allows us to identify how similar, with respect to our "first best", are the "second best" approaches, regarding their overall performance, in the event that they should be considered as post-2012 climate policies.

As we described in Section 1.2.3, we apply the *K-means* clustering method. This method suggests *elbows* between the four and six cluster solutions. Thus, we enforce the *K-means* method to divide the thirteen proposals into four, five and six groups. After a large number of runs, as recommended by Everitt and Hothorn (2006), we find that the five group solution is the most stable regarding its membership. Figure A.1 of the appendix A.4 shows the distribution of the thirteen proposals on the PCA plot along the two first principal components as well as the main result from the cluster analysis. The cluster analysis finds that the *Three-part policy*, the *International agreements on energy efficiency* and *Graduation and deepening* approaches always form a stable policy group. Therefore, besides the *Three-part policy*, we may equally consider, among the remaining twelve approaches, any of these "second best" approaches as candidates for post-2012 climate policy. This finding reveals one main policy implication: that we may not have a unique proposal standing out as candidate for the post-2012 agreement negotiation.

1.5 Conclusions

We develop a grading system to assess thirteen global climate architectures for the post-2012 period based on four criteria: environmental effectiveness, cost effectiveness, distributional considerations and institutional feasibility. Furthermore, we employ two complementary methods: principal components and cluster analysis with the aim of better supporting our findings. We thus obtain two main results.

Firstly, the assessment of the proposals shows that no proposal fulfils all the four criteria with a very good score. This finding suggests that there exist trade-offs among the policy components included in the proposals. In fact, the PCA allows us to identify such internal "rival" elements. On the one hand, the first principal component shows that the higher the number of policy instruments a proposal comprises, the more difficult may be its implementation. Architectures that propose a wide quantity of instruments in order to fulfil the criteria of environmental and cost effectiveness and distributional considerations tend to be infeasible. On the other hand, the second principal component shows that we may not obtain the ideal equitable climate policy architecture without worsening the other architectural dimensions, especially its institutional feasibility. In particular, we find that in these proposals, the main conflicting condition with respect to feasibility is the meaningful U.S. participation.

Secondly, we find that only one proposal, the *Three-part policy*, shows the best performance on the four criteria by attaining a very good score for three and a good score for the fourth. We call this proposal the "first best" option for post-2012 climate policy. In addition, two other proposals obtain an evaluation of good or very good performance for the four criteria: the *International agreements on energy efficiency* and *Graduation and deepening*. We propose these two approaches as the "second best" options if an eventual negotiation and subsequent implementation based on the "first best" approach faces any unexpected contingency. The subsequent cluster analysis finds that the three proposals always form a stable policy group. Hence, they may all be considered as suitable candidates for post-2012 climate policy.

Acknowledgments

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Chapter 2

Stakeholder-based Scenarios for Post-2012 Climate Policy: A Participatory Approach

This chapter is a modified version of Ronal Gainza-Carmenates, Juan Carlos Altamirano-Cabrera, Philippe Thalmann and José Luis Carrasco Terceros (2009), "Stakeholder-based Scenarios for Post-2012 Climate Policy: A Participatory Approach", Carbon & Climate Law Review *3, 248-260.*

Abstract

We performed a study to define the key elements of feasible global climate policy scenarios for the post-2012 UNFCCC regime by contacting - through a series of questionnaires - 149 stakeholders involved in climate-change discussions. We applied a Multiple Correspondence Analysis to the results. We then classified the stakeholders' views into three main groups which we associate with scenarios for post-2012 climate policy. Further, we identified three points with wide consensus among the stakeholders: (i) 2013 is the most likely starting point for the next climate agreement, (ii) flexibility mechanisms will most probably be pursued, and (iii) technology and financial transfers to developing countries are likely to be used as incentives for these countries to undertake a more meaningful climate policy. We found that the type of target for the United States largely determined the type of scenario the stakeholders' envisaged for the post-2012 climate regime. Finally, we can associate stakeholders with a certain scenario taking into consideration their experience in climate change negotiations.

Keywords: *post-2012 climate policy scenarios, stakeholder, multiple correspondence analysis*

2.1 Introduction

Beginning in the early 1970s, the application of scenario analysis to environmental issues has been a well-established field. Since then, environmental scenario analysis has been used to examine many different scales and types of environmental problems, ranging from global sustainability to specific issues such as changes in emissions, air quality, or land cover in a specific region. Environmental scenarios provide an interdisciplinary framework for analyzing complex environmental problems and envisioning solutions for these problems by, for example, establishing a link between environmental science and policy (Alcamo, 2008).

The study of policy scenarios allows us to examine additional policy instruments and targets to those already adopted. The advantages of defining policy scenarios are that they: (i) can incorporate the views of several different stakeholders and experts simultaneously, (ii) can describe a complex system, and (iii) provide a well written, comprehensible storyline, which is an interesting means of communicating information about future policy to policy makers (Alcamo, 2008).

The analysis of policy scenarios is particularly important for environmental policy making because, among other things, they can illustrate how alternative policy pathways may, or may not, achieve an environmental target, and they can provide an opportunity for stakeholders to become involved in the development of public policies (Alcamo, 2008). Involving stakeholders in scenario development enhances the legitimacy and impact of scenarios, which can be a crucial factor in their usefulness to support public decision making (Alcamo and Henrichs, 2008). Further, the study of policy scenarios helps us better understand or predict outcomes in open-ended processes, such as climate-change negotiations. Thus, scenario analysis becomes an important tool to exemplify possible options and outcomes of international climate agreements.

There are two approaches to policy scenarios: analytical and participatory. The analytical approach is developed using available information to express non-mathematical knowledge in an explicit, transparent and reproducible way (e.g. integrated assessment models), whereas in the participatory approaches the scenarios are developed by using the stakeholders' judgment to prescribe events for the future (Alcamo and Henrichs, 2008). The literature on international climate policy gathers mostly analytical approaches for policy scenarios for the post-2012 period.[1] In particular, it focuses on finding mechanisms to achieve more significant participation of DCs and enhancing technology development and sharing of low-carbon technologies. However, proposals addressing these mechanisms often face trade-offs, such as balancing environmental and cost effectiveness, distributional considerations, and institutional feasibility. It is difficult for a single proposal to promote all dimensions simultaneously; enhancing one aspect can compromise the achievement of another (Gainza-Carmenates et al., 2010). Therefore, the implementation of these policy scenarios would be limited.

In this paper, we choose the participatory approach and performed an exploratory study to define key elements of feasible global climate policy scenarios for the UNFCCC post-2012 regime. Our study relied on questionnaires of stakeholders involved in climate change discussions. To attain our objective, we performed a MCA - a geometric method which allowed us to analyze patterns within a large number of categorized variables (i.e., set of questions).[2] This is the first study which applies the MCA framework to identify climate policy scenarios.

With the exception of Böhringer and Löschel (2005), participatory approaches have not been fully exploited with the aim of defining climate policy scenarios for post-2012. They investigated possible post-Kyoto climate policy scenarios by asking experts about the probability of the occurrence of four variables: (i) required emission reduction, (ii) U.S. participation in the abatement coalition, (iii) participation of developing countries in the abatement coalition, and (iv) burden sharing rules of abatement duties. Then, by employing a cross impact matrix, experts estimated how the occurrence of each event would impact the probability that all the other events would occur.

They obtained three main results: (i) post-2012 agreements would result only in small reductions in GHG emissions, with abatement duties predominantly assigned to the ICs;

[1] For a list of analytical approaches for post-2012 climate policy, see Gupta et al. (2007).

[2] Categorized variables: for each question (variable) there are a finite number of response categories.

(ii) DCs would remain uncommitted, but they would sell emission abatement to the industrialized world; and (iii) equity rules to allocate abatement duties would be mainly based on the "ability to pay principle" (i.e., considering Gross Domestic Product (GDP). Their work has one main caveat - that they imposed on the experts the choices of variables, by defining and assuming the scenario dimensions in advance. Consequently, the experts could not add to or change the categories set by the researchers, which imposed strong constraints on what a post-2012 policy might resemble and thus limited the possible policy combinations (Böhringer and Löschel, 2005). We tried to overcome the caveat of Böhringer and Löschel (2005). First, we extended the scenario dimensions by including six other variables. Second, the stakeholders were free to propose new categories of answers. Finally, the stakeholders could justify their choices by proposing the instruments and paths to implement them.

The remainder of this chapter is organized as follows: Section 2.2 describes the methodological framework for developing post-2012 climate policy scenarios; Section 2.3 presents the analysis of the questionnaires; in Section 2.4 we identify global climate policy scenarios; and in Section 2.5 we conclude.

2.2 Methodology

We followed the participatory approach to construct climate policy scenarios for the post-2012 world. Stakeholders participated in two steps: First, a stakeholders group defined the architectural complexity of the climate-change negotiation process and the possible outcomes of this process (global climate policies) by taking part in a questionnaire-interview. Second, a broader stakeholder group assessed the feasibility of the possible outcomes defined by the first stakeholder group in responding to another survey-questionnaire.

In the remainder of this Section, we explain the three main steps performed in our analysis: (i) carrying out the interviews of twenty-six stakeholders, (ii) applying a worldwide survey to a broader number of stakeholders (123), and (iii) executing MCA of the answers.

2.2.1 The Questionnaires

Stakeholder participation is particularly important in projects that aim to create an open-ended learning dialogue about the outcome of a process (Pahl-Wostl, 2008). In our case, this is the negotiation process, which aims to reach an agreement on the post-2012 climate regime. The choice of different stakeholder groups is an important factor in the participatory process since there are different kinds of stakeholders, depending on their role and/or position. In this study, 149 stakeholders from 48 countries participated[3]. We identified the following groups: *Governmental* (i.e., ministers, negotiators and climate policymakers), *Intergovernmental* (i.e., representatives of United Nations secretariat units, bodies and specialized agencies and other intergovernmental organizations), *Academia*, *Business*, *Media* and Non-Governmental Organizations (NGOs).

The design of the questionnaires followed the four standard steps for this type of study, used in sociology, as described by Grawitz (2000). First, we defined the questionnaire content (i.e., the objective); second, we chose the type of questions (i.e., closed or open, or pre-elaborated questions); third, we checked the appropriateness of the vocabulary; finally, we verified that the number and order of the questions was adequate.

The Interview-questionnaire

After identifying the stakeholders involved in the climate change negotiation process, we developed an interview-questionnaire with the aim of exploring the architectural complexity of the climate change negotiation process and the possible outcomes (global climate policy). We designed this questionnaire to interview stakeholders face-to-face.[4] The average time of the interviews was about 45 minutes. The dialogue was recorded. The interview technique was an adequate tool in our exploratory study. The direct exchange with stakeholders, who have a deep understanding of the issues analysed, allowed us to access inside knowledge and data that would otherwise not be available (Alcamo and Henrichs, 2008).

The assumptions and hypotheses that served to design the questions were a result

[3] For a list of the affiliation of stakeholders, see Appendix B.1.

[4] We made the questionnaire available in English, French and Spanish.

of a preliminary literature review of post-2012 approaches proposed by scholars as well as considering the features of the current climate regime (UNFCCC and Kyoto Protocol).[5] We grouped the questions into six general topics: (i) the feasibility of a short-term GHG emission reduction target and a long-term stabilization goal and the timetables for these objectives (e.g., *For the next commitment period, is it feasible to include a long-term stabilization goal?*); (ii) flexibility provisions designed to lower the cost of implementing a global climate policy (e.g., *Among the different instruments proposed by the economists to lower the cost of implementation of a global climate policy, which one or ones will be included in a future climate treaty?*); (iii) burden-sharing rules for mitigation and adaptation efforts, as well as for financing the cost of impact to climate change (e.g., *What kinds of burden sharing rules are likely to be considered to answer the issue of equity in a future climate policy?*); (iv) how the RD&D of low-carbon technology will be introduced into a post-2012 climate policy (e.g., *Which technology-specific elements will be included in a new commitment period?*); (v) measures to encourage the United States and DCs to play a more active role in climate-change issues (e.g., *What kind of incentives will be used to attract the United States of America to participate in a new commitment period?*); (vi) the stakeholder's personal considerations concerning a post-2012 climate policy scenario (e.g., *Which are the most controversial issues in the current climate change negotiations process?*).

We interviewed stakeholders linked to climate-change negotiations from the European Union, Switzerland and major developing countries such as China, India and Brazil. In total, we contacted 36 experts at this stage, and 26 stakeholders participated. Among them, we personally interviewed 20. Four preferred to answer the interview in writing and the remaining two answered the interview by telephone. In this step, the stakeholder spectrum was: 12% *Governmental*, 4% *Intergovernmental*, and 23% *Academia*. The largest number came from NGOs, with 62% of participants. As indicated above, we assumed that NGOs are organizations which protect the interests of a group of citizens as well as research institutions, networks, and business and academic associations, etc.[6] After a preliminary processing of the data, we realized that five interviews had a substantial amount of miss-

[5] For a summary of post-2012 approaches, see e.g. Bodansky et al. (2004).

[6] In this step, stakeholder type Media did not participate.

ing information. Thus, they were not used in the final data analysis. Therefore, we finally analyzed twenty-one interviews.

We analyzed the interview answers in four stages: (i) transcription of the recorded interviews; (ii) verification and interpretation of each interview to establish the intended correlations - searching for blanks, verifying that the responses in each interview were relevant, seeking response uniformity, and ensuring that those interviewed had clearly understood the content of the survey; (iii) grouping of questions, given that our main goal was to search information about a fact (feasible climate policies), rather than to study the respondent's behaviour, the assemblage of each answer being made question by question (horizontally); and (iv) codification - establishing specific categories of answers. Further, we considered that for closed questions there were two possible answer categories (yes and no), whereas answers for open questions were classified by common points and similarities (e.g., tendency or affinity).

The Survey-questionnaire

Drawing on the results from the interviews in the first step of this study, we highlighted the main beliefs of the interviewees concerning the features of viable global climate policies for the post-2012 period. In order to assess the feasibility of the different climate policy elements identified, we created a new questionnaire (See Appendix B.2), which we sent to a larger number of stakeholders. We posted it on the Climate-L Info Mailing List, administered by the International Institute for Sustainable Development.[7] In addition, we emailed 90 people from government and international organizations linked to the climate-change negotiations, as well as 40 people who participated in the International Scientific Congress on Climate Change held in Copenhagen (10-12 March 2009). Ultimately, 123 people answered this new questionnaire. In figure 2.1, we show the distribution of the stakeholders who participated in the second step.

The survey-questionnaire is, in principle, an adaptation of the interview-questionnaire. Nevertheless, in the new questionnaire, we corrected some of our initial beliefs (see details

[7] The Climate-L Info Mailing List has 25,000 readers worldwide.

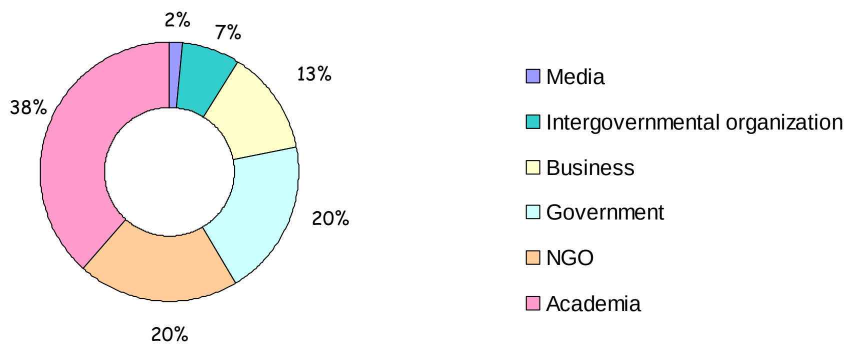


Figure 2.1: Stakeholders' profile of the survey-questionnaire.

in Section 2.3.1). The survey-questionnaire contained closed questions with the answer alternatives (response categories) proposed by the stakeholders interviewed in the first part of this study. However, each question also offered a blank answer option - free to be filled out by the respondent - and some questions were better formulated as a result of lessons learned from the first questionnaire. The closed questions were grouped around: the kind of targets for Annex B countries, the United States and EDC;[8] incentives for the U.S., and EDC participation;[9] elements for technology development and sharing of low-carbon technologies; the kind of flexibility mechanisms to be included; adaptation concerns; and the viable global target for 2030.[10] There were four open questions regarding the respondents' personal views on the most controversial issues in the ongoing negotiation process and the ideal solutions for these issues, as well as the most likely starting date for the next commitment period and its duration (in years).[11]

[8] In the context of this study, the following countries are considered EDC: India, China, Brazil, Mexico, the Republic of Korea and South Africa.

[9] Incentives refer to the rewards and punishments perceived by these countries to be related to their actions and those of others in the context of climate change cooperation.

[10] An example of a closed question: "Among the developing countries, some emerging economies such as China, India, Brazil, the Republic of Korea, South Africa and Mexico are asked to play a more important role in the next commitment period. How will these emerging economies participate in the next commitment period? a) accepting a binding absolute quantitative reduction target (similar to those accepted by Annex B countries under the Kyoto protocol) or, b) accepting a binding indexed target (e.g., ton of CO_2 per dollar of GDP, per capita emission) or, c) accepting a non binding quantitative reduction target with benefit from markets mechanisms (i.e., selling surplus allowances when their emissions are less that their assigned amount, but without penalty in case of no compliance) or, d) other, please specify."

[11] We introduced two other questions related to the personal characteristics of stakeholders in this questionnaire: the stakeholder working type of organization and their earlier experience in the climate-change negotiation process.

2.2.2 Multiple Correspondence Analysis

With the aim of finding answer patterns in the survey-questionnaire, we performed an MCA - which enabled us to analyze the relationships within a large number of response categories of a set of questions by representing them on an MCA plot.[12] The objective of the MCA was to represent the maximum possible variance on a map of few dimensions, usually the first two dimensions (i.e. plot of the principal coordinates). The interpretation of the map involved inspecting how the categories lie relative to one another and how the stakeholders were distributed relative to the categories. In this Section, we describe the main concepts and steps we followed during the MCA analysis (Greenacre, 1993; Lebart et al., 2006).

First, we transformed our survey-questionnaire into a *Standard Format* because for each question there should have been a set of response categories that were mutually exclusive. Therefore, we converted those categories that were not mutually exclusive into dummy variables (i.e., Yes or No categories).[13] We thus obtained a matrix representing the *Standard Format* questionnaire.

Second, to perform the MCA, we followed Greenacre (1993) by employing an indicator matrix - a respondents-by-response category table with as many rows as respondents (n) and as many columns as response categories (k). This nk matrix is a matrix of dummy variables, consisting only of zeros and ones. We obtained an indicator matrix of 123 respondents by 78 response categories. The conversion of the *Standard Format questionnaire* matrix to the indicator matrix was facilitated by the *Binarization* and *Format* tools - both available in the SPAD 7.0 software.[14]

Third, we employed the MCA tool in SPAD 7.0 to perform the MCA analysis. In this step, it was important to define the types of variables - the active and supplementary variables. The active variables are the core of the MCA analysis because they determine the solution

[12] One of the key ideas behind the geometric data analysis is the geometric modeling of variables (i.e., response categories of categorized variables) on a plot of two axes, in this case the MCA plot. The main results arise from the interpretation of this plot.

[13] (i) Technology development and sharing, (ii) incentives for the U.S. and developing country participation, (iii) instruments for adaptation concerns, (iv) flexibility mechanisms, (v) personal views on the most controversial issues in the ongoing climate change negotiation process and (vi) the ideal solutions for this.

[14] SPAD 7.0 is a software used for exploratory data analysis and clustering. It includes tools for surveys and text mining. More details on this software is available on the Internet at http://eng.spadsoft.com/.

space on the MCA plot. These variables help in the interpretation of the axes and in the classification of the individuals. For this study, we considered all categorized variables describing the features of the post-2012 scenario as active variables.

We used the supplementary variables to depict the positions of groups of respondents regarding their characteristics (Greenacre, 1993). Thus, they did not influence the geometric orientation of the axes; rather, they supported and complemented the interpretation of the configuration of categories of active variables. They played no role in the analysis, apart from helping to interpret their positions on the MCA plot.

For the MCA, we employed the response categories represented between a range of 10% and 90%. Categories with a representation greater than 90% (more than 100 stakeholders) were considered a consensus. The SPAD 7.0 randomly distributed categories with a representation of less than 10% and blank answers among the other categories grouped under the same variable.

Finally, we verified the statistical quality of the variables before representing them on the MCA plot, because only significant categories may be represented. Significant active categories were those whose contribution to one of the axes was greater than the average contribution to one axis (Rouanet, 2006). The average contribution was 1.89 for each axis. Significant supplementary categories were those with absolute test value greater than 2, which indicates a significant position of the corresponding category in respect to the axes (Lebart et al., 2006).

2.3 Analysis of the Questionnaires

2.3.1 Analysis of the Interviews

The results from the first step (the interview process) in the stakeholder consultation process was essential for our study, since they allowed us to define likely global post-2012 climate policy elements, based on stakeholders' judgment. This helped us to refine our initial hypotheses, which were based on the literature review of post-2012 approaches proposed by scholars. This process enabled us to re-focus the scenario construction on a specific set of climate-policy elements. For instance, stakeholders did not judge as feasible to include a long-term stabilization target, as considered in some proposals for the post-2012 period.[15]

In addition, stakeholders do not see as feasible the separation of impacts of climate change and their economic costs from the cost of adaptation, as it is considered in some literature.[16] Hence, stakeholders envisaged that the future policy mechanism to tackle adaptation costs will have to also encompass the impacts of climate change and their costs.

Additionally, this step contributed to the reformulation of some architectural aspects. For example, the type of reduction target is closely linked to the type of country. Thus, from the answers of stakeholders, countries can be gathered in three groups: (i) Annex B countries (without the U.S.), which are mostly associated with binding quantified emission limitations and reduction targets; (ii) the U.S. with a binding reduction target (either indexed or absolute), and for which a unilateral climate policy is also considered; and (iii) EDC. For the last group of countries, we also considered non-binding targets.[17] The main result of this step was the construction of the survey-questionnaire.

2.3.2 Analysis of the Survey

We obtained three main statistical results from the analysis of the survey-questionnaire. First, we grouped the "other type" of answer (blank field) of each question into new categories, if it had a significant representation on the MCA plot. This was the case for flexibility mechanisms. We introduced a new response category: the need to reform the current mechanisms by, among other means, introducing a sectoral CDM and extending it to reducing emissions from deforestation and forest degradation.

Second, more than 75% of stakeholders agreed on three points that: (i) the most feasi-

[15] Some post-2012 approaches propose agreeing on a long-term stabilization target at 550 ppm of CO_2 eq. by the end of this century. See e.g. Michaelowa (2007); Höhne et al. (2006); Stavins (2004) .

[16] The impacts of climate change and their economic costs are usually separated in the literature from the adaptations costs (i.e., costs that are assumed to adjust a natural or human system in response to actual or expected climatic stimuli or their effects). See e.g. Watkiss et al. (2005).

[17] In the literature, this is referred to as either non-binding or no-lose targets. We assume EDC are allowed to sell surplus allowances when their emissions are less that their assigned target amount, but without penalty in case of non-compliance. See e.g.: Aldy et al. (2003a).

ble starting date for the next commitment period will be 2013, (ii) CDM projects and ETS of GHG will continue, and (iii) the transfer of low-carbon technologies and the extension of financial incentives (i.e., linking climate change to priority issues of EDC such as poverty reduction) toward EDC will be used to attract these countries to undertake more ambitious climate policy.

Third, we grouped the response categories with the highest number of votes by variable (i.e., the mode). We called this group of answers the "popular" scenario (see table 2.1). The fact that some of these most-voted response categories did not obtain at least 50% acceptance by stakeholders indicates the lack of consensus on some crucial policy elements of the future global climate agreement. Consider the most voted response category for "type of target for EDC": The non-binding target obtained 39% of acceptance by stakeholders, whereas 35% of them believed in the acceptability of a binding indexed target for this group of countries. This rather simplistic statistical analysis of the survey-questionnaire did not allow us to identify a clear stakeholders' position regarding this element. Therefore, we performed an MCA in order to identify stakeholders' positions and search for feasible combinations of instruments, targets and measures of the post-2012 climate policy.

Table 2.1: The “popular” scenario

Response category	Percentage
Starting date in 2013	75.0
Duration of the commitment period of 5 years	42.0
Binding absolute quantitative target for Annex B countries	58.0
Binding absolute quantitative target for the U.S.	56.0
Non-binding target for emerging developing countries	39.0
ETS	81.3
The level of the short-term target will be compatible with +20% of global GHG for 2030 relative to 2000 emissions	47.0
The U.S. climate policy will be conditioned mostly by international political reasons	70.7
The enhancement of technology transfer as an incentive for emerging developing countries participation	82.9
Voluntary technology agreements to foster RD&D	60.2
Linking adaptation to other fields (i.e., development cooperation)	69.9
The most controversial issue is setting the reduction targets by group of countries	65.0
The solution for setting reduction targets is exhausting political negotiations	36.7

2.4 Identifying Post-2012 Climate Policy Scenarios

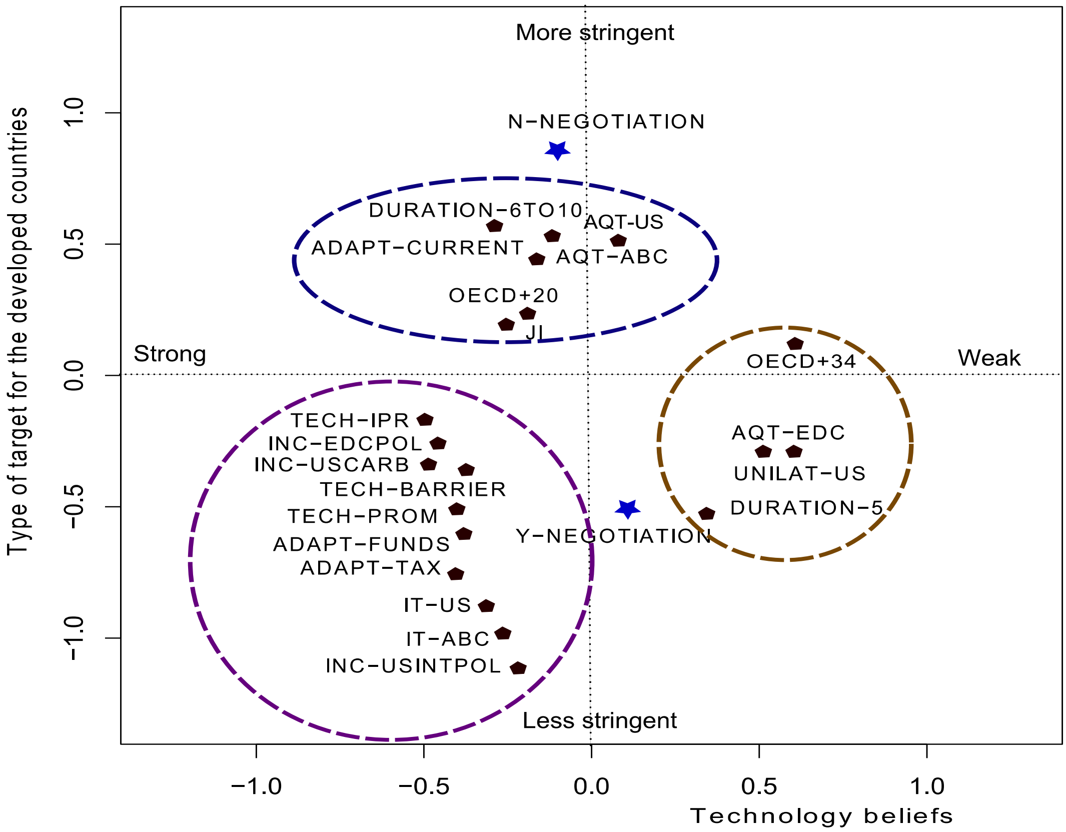
In figure 2.2, we represented the distribution of the Euclidean distance of the significant categories on a two-dimensional plot.[18] We represented active categories as polygons and supplementary categories as stars. Among overall active variables, those which most contributed to interpreting the MCA plot were: the type of target for the U.S. (15.8%), the type of target for Annex B countries (15.7%), and the reduction of tariff barriers (i.e., border taxes) in EDC for low-carbon technologies (12.1%). In other words, the type of categories chosen by stakeholders for these variables - in particular the type of target for the U.S. - affected the distribution of the other response categories. Hence, on the MCA plot, we obtained three main groups of pattern answers.

The y-axis could be interpreted as "type of target for the developed countries", since it opposes clearly stringent targets for these countries (i.e,. absolute quantitative targets) in the top centre of the plot (AQT-ABC, AQT-US) against more flexible targets for these countries in the bottom, either an indexed target for the U.S. (IT-US) and Annex B countries (IT-ABC) or the implementation of a meaningful domestic climate policy by the U.S. (UNILAT-US). The x-axis mainly reflects the opposition between stakeholders concerning their views about the importance given to the development and deployment of low-carbon technologies for the next commitment period.

Two variables contributed most to the formation of this axis. On the left side of the plot, we find stakeholders who believe that for the next commitment period, the promotion of this kind of technology will be favoured by changing the rules of the intellectual property rights system (ECH-IPR) and by reducing tariff barriers in developing countries (TECH-BARRIER). These variables contribute 9.6% and 10.7%, respectively, to the construction of this axis.[19] On the opposite side (right) are respondents who do not choose these response categories. The x-axis could be called "technology beliefs". Thereafter, we centred our analysis on explaining the relationships depicted by the significant categories on the MCA map, in order to define feasible climate policy scenarios for the post-2012 climate regime.

[18] The Euclidean distance is the distance between two points that one would measure with a ruler. For a full mathematical explanation, see e.g. Everitt and Hothorn (2006).

[19] For a statistical summary of the active varibales, see table B.1 in the Appendix B.3.



Abbreviations

DURATION-6TO10	Duration of the commitment period from six to ten years
AQT-US	Binding absolute quantitative target for the U.S.
ADAPT-CURRENT	Adaptation funds should be enlarged by getting a part of revenues from the current mechanisms
AQT-ABC	Binding absolute quantitative target for Annex B countries
OECD+20	The level of the short-term target will be compatible with +20% of global GHG for 2030 relative to 2000 emissions
JI	Joint implementation projects
TECH-IPR	The intellectual property right system is re-negotiated
INC-EDCPOL	Political and/or economic coercion on EDC to take more ambitious climate policy actions
INC-USCARB	The U.S. perceive the availability of the carbon market as an incentive to participate
TECH-BARRIER	Reduction of the tariff barriers in developing countries for low-carbon technologies
TECH-PROM	Agreement on RD&D of low-carbon technologies
ADAPT-FUND	Adaptation concerns will be handled by using other international funds
ADAPT-TAX	Implementing a global adaptation levy
IT-US	Binding indexed target for the U.S.
IT-ABC	Binding indexed target for Annex B countries
INC-USINPOL	The U.S. climate policy will be conditioned mostly by international political reasons
OECD+34	The level of the short-term target will be compatible with +34% of global GHG for 2030 relative to 2000 emissions
AQT-EDC	Binding absolute quantitative target for emerging developing countries
UNILAT-US	The U.S. apply an unilateral domestic policy
DURATION-5	Duration of the commitment period of five years
N-NEGOTIATION	Stakeholders without experience in the climate-change negotiation process
Y-NEGOTIATION	Stakeholders with experience in the climate-change negotiation process

Figure 2.2: Projection of the significant categories on the MCA plot.

Considering the distribution of the active significant response categories around the "type of target for the U.S.", we identified three scenarios or patterns of results in our stakeholders' sample:[20] the (i) *"Kyoto redux"* scenario - the group that thinks that the next commitment period will appear more or less a continuation of the current situation (top of figure 2.2); (ii) *"Pro-growth"* scenario - stakeholders who believe that climate change will be tackled in relation to measures addressed to foster, or at least to sustain, economic growth (bottom-left of figure 2.2); and (iii) *"Outside-Kyoto"* scenario - instruments and policies aimed mainly at players not currently bound by the Kyoto commitments (bottom-right of figure 2.2). In the following, we describe the main features of these three climate policy scenarios.

In *"Kyoto redux"*, the duration of the next commitment period will be 6 to 10 years. For this period (from 2013 to either 2019 or 2023), Annex B countries currently under the Kyoto Protocol and the U.S. will assume binding absolute quantitative reduction targets. The level of the short-term targets to agree upon will be compatible with an increase of 20% of global GHG emissions for 2030 relative to 2000 emissions.[21] JI in addition to the CDM and the ETS will remain as flexibility mechanisms.[22] Stakeholders think that the adaptation funds will be enlarged by getting a part of revenues from current mechanisms (i.e., ETS).

"Pro-growth" includes features that deal with more moderate reduction targets for Annex B countries and the U.S.: binding indexed targets (based either on the tons of CO_2 per dollar of GDP or on per capita emissions).[23] In order to enhance the deployment of low-carbon technologies, the agreement includes two measures: first, the renegotiation of the Intellectual Property Rights (IPR) system and, second, the reduction of tariff barriers (i.e., border taxes) for low-carbon technologies by EDC.[24] These measures will be a result of a

[20] In addition to the features that we will describe for each scenario, the three majority views identified in Section 2.3.2, second paragraph, will have to be added to these scenarios.

[21] In the survey-questionnaire, we asked stakeholders to choose among different levels of GHG emissions for 2030 relative to 2000 emissions (an increase of 52%, 34%, 23%, 20% and 7%) - same as those proposed in the OECD environmental outlook to 2030 (OECD, 2008).

[22] All three scenarios identified contain CDM and ETS as flexibility mechanisms. See second paragraph of Section 2.3.2.

[23] Stakeholders who identify this scenario as the post-2012 climate policy do not associate these binding indexed targets to specific timetables and emission pathways. This fact may mean that, for them, it is primordial to focus climate-change negotiations on other architectural elements, instead of starting by setting up timetables and emission pathways. Hence, it is significant to note that 11% of stakeholders from the survey-questionnaire did not take a position regarding the emission pathways (i.e., global GHG emission targets for 2030 relative to 2000 emissions).

[24] Generally, developing countries emphasize the negative role that the IPR system plays in technology transfer, while developed countries have a keen interest in protecting patents developed by their domestic industries. See Meyer-Ohlendorf and Gerstetter (2009).

strong political commitment from all parties that take part in the agreement. The expected implementation of these two measures is *a priori* a win-win situation where both parties (EDC and ICs) enjoy the benefits of the deployment of technologies. On the one hand, the IPR system is modified in order to facilitate the adoption of low carbon technologies for EDC, which will reduce their cost of acquisition of these technologies. On the other hand, ICs will benefit from a reduction and/or elimination of tariffs barriers, such as quota, which would lead to an average increase of trade of some low-carbon technologies, as ICs are the main producers of this kind of technologies (Meyer-Ohlendorf and Gerstetter, 2009).

In this climate policy scenario, the technology market is crucial in tackling climate-change goals. The only way for EDC to participate is by a rapid introduction and use of low-carbon technologies. In this framework, the availability of the carbon market and the international context favour the participation of the U.S. in the agreement. Adaptation concerns are handled by the implementation of a global levy (i.e., taxing fossils fuels) and by using other international funds (i.e., Official Development Assistance, World Bank, Millennium Development Goal, UN Food and Agriculture Organization funds, disaster management, etc.). This approach highlights the potential role of carbon markets in achieving emission reductions.

"Outside-Kyoto" characterizes participation of parties without binding reduction commitments in the current climate regime. According to this group of answers, in the next commitment period - which will have a duration of five years (2013 to 2018) - the U.S. will decide to remain outside and apply a unilateral climate policy as up to now. Nevertheless, this group of stakeholders think that EDC will participate in an agreement with binding absolute quantitative reduction targets (i.e., similar to those accepted by Annex B countries under the Kyoto protocol). In other words, these stakeholders advocate the focus on mitigating actions in EDC, which will be the major GHG-emitters in future decades. In this scenario, the level of the short-term target to agree upon (until 2018) would be compatible with an increase of global GHG emissions by 34% for 2030 relative to 2000 emissions.

Regarding the supplementary categories, only two of them have a significant position on the MCA plot (test value greater than 2).[25] They relate to the stakeholders' earlier participation in climate-change negotiations. On the one hand, stakeholders without experience have a tendency to choose elements included under "Kyoto redux". As this group of stakeholders do not participate in the current climate-change negotiations, they mostly chose well established and known policy elements of the current climate regime (e.g., absolute quantitative targets for ICs and to pursue with the current financial mechanism to tackle adaptation). They believe that the best solution will look more or less like a continuation of the current climate regime. On the other hand, stakeholders with some experience in the negotiation process have a tendency to choose policy elements either under *"pro-growth"* or *"outside-Kyoto"*. We assumed that the stakeholders who believe that the next climate agreement will look like the *"pro-growth"* scenario were the most optimistic, since they felt that significant linkages will be established among the climate agreement and other international agreements, such as WTO's Agreement on Trade Related Aspects of Intellectual Property Rights (TRIPS) and the envisaged elimination of tariff and non-tariff barriers to environmental goods (currently under discussion in the WTO Committee on Trade and Environment).[26,27] Then, we assumed that stakeholders who associate the post-2012 climate regime with the *"outside-Kyoto"* scenario are those who are extremists in their previsions and think that the U.S. will not take part in the agreement, which will be substituted, in some way, by a meaningful participation of EDC in the agreement with reduction targets.

Finally, 65% of stakeholders think that the most controversial issue in the climate-change negotiation process is the way targets are set. However, these supplementary categories - as well as the solutions proposed for them - do not obtain a relevant position on the MCA plot. Moreover, none of the stakeholder types show a consensus for the three groups of possible scenarios identified. This fact shows the disagreement and uncertainty prevailing with respect to the shape of the future climate agreement.

[25] For a statistical summary of the supplementary variables, see table B.2 in the Appendix B.4.

[26] TRIPS: Agreement on Trade-Related Aspects of Intellectual Property Rights. For more details about this Agreement, visit the related website of the World Trade Organization: `http://www.wto.org/english/tratop_e/trips_e/t_agm0_e.htm`

[27] For an interesting summary of the evolution and the state of the art of the relation between Trade and Climate Change, see Tamiotti et al. (2009).

2.5 Conclusions

We defined the key elements of feasible global climate policy scenarios for the post-2012 UNFCCC regime. To do so, we contacted - by means of questionnaires - 149 stakeholders involved in climate change discussions from Government, Intergovernmental, Academia, NGOs, Media and Business.

From this, we obtained four key results: First, we identified that only three issues obtained a broad consensus among stakeholders (more than 75%): that (i) the most probable starting date for the next climate agreement will be 2013, (ii) CDM projects and ETS will continue in place, and (iii) the fostering of technology and financial transfers to developing countries will be used as incentives to entice these countries to undertake more ambitious climate policy. These response categories can be considered as base assumptions for all the subsequent scenarios that we identify.

Second, we identified three main groups of stakeholders' responses: (i) that the world will continue more or less with the current architecture (*"Kyoto redux"*); (ii) climate change issues have to be linked to economic growth (*"pro-growth"*); and (iii) policies designed for key players which are not currently bound by the Kyoto protocol (*"outside-Kyoto"*).

Third, we found that the type of target assumed by the stakeholders for the U.S. largely determines the type of scenario they envisage for the post-2012 climate regime. This variable turned out to be the most distinguishing factor in the study. It contributes most to the interpretation of the MCA plot.

Finally, we can associate stakeholders with a certain scenario, taking into consideration their experience in negotiations. On the one hand, stakeholders with some kind of experience in the climate-change negotiation process envisage a post-2012 climate agreement similar to the *"pro-growth"* or *"outside-Kyoto"*. On the other hand, the *"Kyoto redux"* scenario is seen as most likely by stakeholders without any experience in the climate-change negotiation process.

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Chapter 3

Transfer Design and Incentives for Nationally Appropriate Mitigation Actions in Developing Countries

This chapter is a modified version of the NCCR-Climate Working paper of Ronal Gainza-Carmenates, Philippe Thalmann and Juan Carlos Altamirano-Cabrera (2010), "Transfer Design and Incentives for Nationally Appropriate Mitigation Actions in Developing Countries" which has been recently submitted to a peer review journal.

Abstract

Transfers would play a key role in the implementation of NAMAs in developing countries. In this paper, we analyze the desirable features of such transfers - i.e., *individually rational*, *budget-balanced*, anti-incentives for *free-riding* and *misrepresentation*. We model NAMAs as a non-cooperative, one shot game. We consider NAMAs under two alternative transfer schemes: a *horizontal equity-based* transfer and an "optimal" transfer scheme that we call *à la Weikard*. Our analysis is further refined by the inclusion of the notion of pivotal countries. We find, firstly, that both transfer schemes may allow the implementation of an *individually rational* and *budget-balanced* NAMAs portfolio; secondly, that the transfer *à la Weikard* is more effective in avoiding free-riding. Thirdly, both transfer schemes fail to avoid *misrepresentation* of costs and benefits from reductions in greenhouse gas emissions. Finally, pivotal countries for NAMAs are the most interested in its implementation even if they are the largest transfer contributors.

Keywords: climate policy, Nationally Appropriate Mitigation Actions, Transfer schemes

3.1 Introduction

The most recent round of negotiations under the UNFCCC gave birth to the Copenhagen Accord. One of the main points of this document is to describe the expected role of DCs in the post-2012 climate regime (UNFCCC, 2009). The accord mainly focuses on three points: i) GHG emissions peaking, ii) mitigation commitments and iii) funding and reporting. First, it recognizes that the time frame for GHG emissions peaking will be longer in Non-Annex I countries, since they will prioritize economic development and poverty eradication. Second, their mitigation efforts will be distinct from mitigation commitments of developed countries (Annex I under the UNFCCC), both in magnitude and in legal nature as stated in the Bali Action Plan (UNFCCC, 2007), since they will undertake NAMAs. Finally, NAMAs seeking foreign funding have to be registered and are subject to international Measurement, Reporting and Verification (MRV).

Following Kaul et al. (2003), we may think of NAMAs as a case of a global public good. The good would be the damages which are avoided by reducing GHG emissions. Its public good nature stems from the fact that no country may be excluded from the benefits of reducing GHG in any region of the planet. The adequate provision of this global public good depends, to a large extent, on the transfer scheme used to provide it. Thus, a key point for the functioning of NAMAs is the design of adequate transfers to allocate funding among Non-Annex I countries. Furthermore, there are two other main issues in NAMAs: (i) both the amount of the transfer and the envisaged level of mitigation efforts are voluntary declarations for countries, and (ii) the implementation of both an MRV system to corroborate financing and GHG reduction efforts may be a complex and not a politically neutral task. Therefore, well-designed transfer schemes are needed, which self-enforce the participation of countries, and thus improve the reduction of GHG emissions.

For the provision of a public good, the design of transfers has been essentially centered on schemes which help to reveal the true valuation that agents have of the public good (i.e., asymmetric information). One of the most important contributions in this field has been provided by Myerson and Sattertwhaite (1983). They show that there is no transfer scheme which simultaneously avoids asymmetric information:[1] it is individually rational, i.e., agents are not worse-off when participating; it is budget-balanced, i.e., total transfers are not negative; and it allows the (efficient) provision of the public good.

Two well-known transfer schemes which avoid asymmetric information are the *Clarke-Groves* (Clarke, 1971; Groves, 1973) and the *d'Aspremont-Gérard-Varet* mechanisms (d'Aspremont and Gérard-Varet, 1979). Emons (1994) analyzes the provision of environmental protection measures by means of these two mechanisms. He observes that *Clarke-Groves* transfers are not budget-balanced, and that under the *d'Aspremont-Gérard-Varet* transfers some agents are worse-off by participating. Miljkovic (2009) analyzes the provision of a global public good through the *Clarke-Groves* transfer. He corrects the budget-balance problem by setting up some conditions (e.g., by allowing participation only to countries with positive initial valuations on the public good). However, he determines that if there are countries which are pivotal for the provision of the good, i.e. - the good is not provided if they do not participate, then all the necessary conditions for such a mechanism cannot be satisfied.

For the case of global climate policies, Rose et al. (1998) propose transfer schemes for allocating GHG emission allowances among countries. More recently, Nagashima (2010) summarizes, in-depth, the alternative transfers employed in the literature to tackle global climate policies as well as the main results found due to their implementation, in particular to avoid free-riding. The transfers may be in the form of side payments, emissions permit trading or surplus sharing, and they have been mainly focused on one particular issue, namely the curtailing of free-rider incentives.

In this paper, we analyze the desirable features of transfers for NAMAs - i.e., *individually rational*, *budget-balanced*, anti-incentives for *free-riding* and *misrepresentation*. We model NAMAs as a non-cooperative, one shot game. Particularly, we analyze a NAMAs portfolio under two alternative transfers: a *horizontal equity-based* and a so-called "optimal" transfer which is a reformulation of a transfer proposed by Weikard (2009) which we call, hereafter, a transfer scheme *à la Weikard*. We think that these transfer schemes may be considered

[1] A transfer scheme designed with the aim of avoiding asymmetric information is called *mechanism* by the literature of mechanism design problems.

for the implementation of NAMAs in a post-2012 global climate policy since they include attractive ways to distribute surplus among countries to reduce GHG emissions. On the one hand, the *horizontal equity-based* transfer allocates the surplus payoff following an egalitarian rule (i.e., every participating country receives the same final payoff from avoiding climate change) and the transfer *à la Weikard* shares the surplus payoff in order to compensate the countries' outside payoffs (i.e., when free-riding). Though pursuing a similar objective, they differ in that the *horizontal equity-based* transfer, we observe, is a pragmatic transfer in the sense that it is the simplest way to distribute the surplus payof. On the other hand, the transfer *à la Weikard* is a more elaborate transfer and it is considered as an "optimal sharing rule" in the sense that it minimizes incentives to free-ride.

The main contributions of this paper are four: (i) we analyze NAMAs as a global public good in a game theoretical framework; (ii) we identify countries' behaviors (i.e., misrepresentation) and deviations from full cooperation (i.e., free-riding), (iii) we test for transfers that may alleviate these problems, and (iv) we study the role of pivotal countries. The remainder of this paper is organized as follows: Section 3.2 analyzes the NAMAs design problem; Section 3.3 examines the implementation of NAMAs by means of the *horizontal equity-based* transfer and a transfer *à la Weikard*; Section 3.4 illustrates our results via an illustrative example; and Section 3.5 draws some policy implications and concludes.

3.2 The NAMAs design problem

3.2.1 The model of a NAMAs portfolio: full cooperation

We propose to analyze a NAMAs portfolio as a contract among countries. We model the negotiation of such a contract as a non-cooperative,[2] one-shot game.[3] The set of players are countries $i = 1, 2, 3, \ldots, I$. which negotiate to participate in a NAMAs coalition. A NAMAs coalition may be formed as long as the coalition includes both Annex I and Non-Annex I countries. We refer to the case where all candidate countries sign the contract as

[2]Games may be also designed in a cooperative way. For an example of solution for the design of cooperative environmental agreements, see for instance, Chander and Tulkens (1995).

[3]The model described in this section should be applied, in principle, to other types of situations than NAMAs. For instance, in the design of a global climate policy centered on GHG mitigations.

the grand coalition G. Countries negotiate to cooperate in implementing a NAMAs portfolio for one economic sector or a nationwide program. The implementation of this NAMAs portfolio means that each DCs may propose one NAMAs program (its strategy) among a set of possible alternative programs. Note that in NAMAs, Annex I countries do not carry out mitigation activities. Then, the NAMAs program proposed by country i entails "national" (or sectoral) GHG emission reduction x_i.

For simplicity, we assume that x_i is the strategy of country i when it is called on to play. The total GHG emission mitigation (i.e., coalitional target) from the implementation of this NAMAs portfolio is given by $X_G = \sum_{i=1}^{I} x_i$. We further define the set of emissions as $\vec{X}_G = \{x_1, \ldots, x_I.\}$ with costs $C_G(\vec{X}_G) = \sum_{i=1}^{I} c_i(x_i)$.[4] We denote as $\overline{S}$ the volume of GHG emissions before NAMAs and by $\underline{S}$ the final volume of GHG emissions after the implementation of the NAMAs portfolio, so that $X_G = \overline{S} - \underline{S}$.[5] We consider that NAMAs are implemented as a complement of a post-2012 global climate policy (e.g., at least a Kyoto forever scenario). We assume that mitigation actions which are carried out by Non-Annex I countries through the CDM and financed by the Global Environmental Facility (GEF) are not included in the NAMAs portfolio.[6] Note that there is no burden-sharing rule to distribute GHG abatement among participating Non-Annex I countries as NAMAs is a voluntary declaration for them.

We assume that countries are not identical. They differ in two parameters: abatement costs and willingness to pay for the NAMAs portfolio. Developed countries do not incur costs because they take part uniquely by financing NAMAs. Note that NAMAs portfolios may not lead to Pareto optimal outcomes since all Non-Annex I countries are asked (as under the Copenhagen accord) to carry out mitigation activities regardless of their marginal abatement costs. Thus, countries may propose other x_i different to their efficient solution, i.e., where marginal costs and benefits from abatement are equal[7]. Countries reveal their

[4] We consider that countries may propose "no-regret options" (i.e., mitigation opportunities with net negative costs). These options have benefits such as reduced energy costs and reduced emissions of local/regional pollutants which equal or exceed their costs to society, excluding the benefits of avoided climate change (IPCC, 2007). Bottom-up studies suggest that mitigation opportunities with net negative costs have the potential to reduce emissions by about 6 $GtCO_2$-eq/yr in 2030 (IPCC, 2007).

[5] We do not consider decay rate effects for these GHG emissions.

[6] The GEF supports projects in Non-Annex I countries that reduce or avoid GHG emissions in the areas of renewable energy, energy efficiency, and sustainable transport.

[7] One rationale for our assumption is that, for instance, the level of GHG reduction targets agreed under the Kyoto protocol was set up regardless of cost-benefit analysis. For a discussion on the cost inefficiency of targets under the Kyoto protocol, see McKibbin and Wilcoxen (2002).

willingness to pay for the NAMAs portfolio $\theta_i(X_G)$, which is increasing in X_G. We assume that this parameter is a direct measure of the damages $D_i(X_G)$ which are avoided by reducing X_G. Country i perceives with the implementation of the NAMAs portfolio, an environmental gain $\theta_i(X_G) \equiv D_i(\overline{S}) - D_i(\underline{S})$, with $D_i(\overline{S})$ as damages expected if the NAMAs portfolio does not occur and $D_i(\underline{S})$ as damages expected if the NAMAs portfolio occurs.[8] Then, the total environmental gain from the implementation of the NAMAs portfolio is $\Theta_G(X_G) = \sum_{i=1}^{I} \theta_i(X_G)$, and $\vec{\Theta}(X_G) = \{\theta_1(X_G), \ldots, \theta_I(X_G).\}$. We denote $\widehat{v}_{i\in G}(\cdot)$ as the initial payoff for country i and it is defined as follows: $\widehat{v}_{i\in G}(X_G, x_i) = \theta_i(X_G) - c_i(x_i)$. We allow countries to make transfers $t_i \in \Re$ among them. If $t_i > 0$ country i contributes with the financing of NAMAs programs abroad, otherwise it receives a subsidy to carry out its NAMAs program. The sum of total transfers is denoted by $T = \sum_{i=1}^{I} t_i$, with $\vec{T} = \{t_1, \ldots, t_I.\}$. Country i receives the following final payoff if it participates in the coalition:

$$v_{i\in G}(X_G, x_i, t_i) = \theta_i(X_G) - c_i(x_i) - t_i. \tag{3.1}$$

Countries cooperate freely in the implementation of a NAMAs portfolio. We expect that a minimum requirement for a country i to cooperate is that it receives, at least, an equal final payoff than in the *status quo*.[9] Thus, we state that cooperation must be *individually rational* and the following condition be upheld:

(i) The final payoff of every country is non-negative: $v_{i\in G}(X_G, x_i, t_i) \geq 0, \forall i$.

We assume that there is no source of funds (beyond countries' transfers) to finance a NAMAs portfolio. One rationale for that is the current scarcity of international funds to provide a global public good. Therefore, we consider that a NAMAs portfolio is *budget-balanced* if the following condition is satisfied:

(ii) Total transfers are not negative: $T \geq 0$.

In addition, we consider that a necessary requisite for the implementation of a NAMAs

[8] In this paper, we do not consider that countries could benefit from climate change (i.e., $\theta_i(X_G) < 0$). We base our assumption on the fact that NAMAs is a policy instrument focused on Non-Annex I countries and that the impact of climate change on these countries is expected to be negative, particularly larger than that for developed countries for 4° of warming (IPCC, 2007).

[9] We define as *status quo*, the case where there is not abatement reduction at all due to the implementation of a NAMAs portfolio, that is $\theta_i(0) = 0$.

portfolio is the following *feasibility condition*:

(iii) The total environmental gain equals or exceeds total cost: $\Theta_G(X_G) \geq C_G(\vec{X}_G)$.

We comprehend (iii) from the *efficient provision decision rule* of a discrete public good stated firstly by Samuelson (1954). There, the public good should be provided if the sum of consumers' reservation prices exceeds the cost of providing the public good, otherwise the *status quo* should be kept. In our analysis, the public good (i.e., avoided impacts from reduction in GHG emissions) may be considered as a continuous public good since the total GHG mitigation potential $\vec{X}_G$ depends on how many countries i take part in coalition G. Note that (i) and (ii) entail (iii). By (i), we obtain the result that $v_{i\in G}(X_G, x_i, t_i) \geq 0$, then $\sum_{i=1}^{I} v_{i\in G}(X_G, x_i, t_i) \geq 0$ which is the same as $\Theta_G(X_G) - C_G(\vec{X}_G) - T \geq 0$; and by (ii), $T \geq 0$, then necessarily $\Theta_G(X_G) - C_G(\vec{X}_G) \geq 0$.

Definition 1. *A NAMAs coalition G is individually rational, balanced and feasible if there is, at least, one set $\{\vec{X}, \vec{T}\}$ that meets conditions (i), (ii), and (iii) $\forall i \in G$.*

We found, in the literature, that the existence is possible of pivotal agents for the provision of a public good (Clarke, 1971; Groves, 1973). More recently, Miljkovic (2009) again takes up this concept for the case of the provision of a global public good. He glimpses the possible presence of pivotal countries within international organizations. We consider it useful to study the role of pivotal countries in the implementation of NAMAs.

Let $\Theta_{G-j}(X_{G-j})$ and $C_{G-j}(\vec{X}_{G-j})$, be the total willingness to pay and the total cost of coalition G without country j, respectively, with $X_{G-j} = X_G - x_j$ and $C_{G-j}(\vec{X}_{G-j}) = C_G(\vec{X}_G) - c_j(x_j)$ and $\Theta_{G-j}(X_{G-j}) = \sum_{i=1}^{I} \theta_{i\notin j}(X_{G-j})$.[10]

Definition 2. *Assume that the grand coalition G is formed and that (iii) holds. Then, j is a pivotal country if when j withdraws from G, (iii) does not hold anymore (pivotal effect):*[11]

$$\Theta_{G-j}(X_{G-j}) - C_{G-j}(\vec{X}_{G-j}) < 0. \tag{3.2}$$

[10] Thereafter, we denote as j a country which is the only one having a different behavior compared to the other countries $i \in G$.

[11] This condition may not be associated with the non-essentiality definition of Weikard (2009). There, a player j is non-essential for a coalition if, whether j takes part or not in the coalition, no country has an incentive to withdraw from the coalition. Following our pivotal definition, it should be the case that a non-pivotal country might be essential or not essential for the coalition.

A pivotal country is necessarily one for which $\theta_j(X_G) >> c_j(x_j)$. Note that country j may be both an Annex I country or a DCs - e.g., Annex I countries with high benefits from avoiding GHG emissions and Non-Annex I countries with low marginal abatement costs and high benefits. For the purposes of this paper, we classify the national NAMAs programs, as described in the Copenhagen Accord (UNFCCC, 2009), into two categories: (i) unilateral NAMAs that are self-financed actions undertaken by Non-Annex I countries, and (ii) supported NAMAs that are programs which need some monetary transfer from developed countries.

3.2.2 Countries' behaviors and deviations from full cooperation

Unfortunately, finding a set $\{\vec{X}, \vec{T}\}$ that meets (i) to (iii) is not enough to guarantee that countries will fully cooperate when implementing a NAMAs. There are some issues such as free-riding and asymmetric information that may still doom to failure the implementation of a NAMAs portfolio as in definition (1). In the following, we analyze how these issues may act under a NAMAs portfolio and we propose some conditions which help in dealing with them.

Anti-free-rider incentives

Cooperation on GHG mitigation is plagued by free-riding since the output of mitigation activities can be viewed as a global public good.[12] Therefore, it would be expected that NAMAs will have to deal with this problem. As participation of Non-Annex I countries is voluntary, they should base their decision to participate in NAMAs on their payoffs when participating in coalition G (i.e., equation 3.1) and when remaining outside and enjoying the benefits of the avoided GHG mitigation efforts made by the other countries (i.e., free-riding). In the free-riding case, equation (3.1) becomes:

$$v_{j \notin G}(X_{G-j}, 0, 0) = \theta_j(X_{G-j}). \tag{3.3}$$

[12] For a game theoretical survey of this problem in international cooperation on climate change agreements, see for instance Böhringer et al. (2002). For some policy implications related to free-riding in climate change negotiations see Banuri et al. (2001).

Note that the outside payoff $\theta_j(X_{G-j})$ of a country j when it is pivotal for the implementation of a NAMAs portfolio is zero since $X_{G-j} = 0$. We introduce the *no-free-rider incentive condition* into the analysis by substituting (3.3) in (i). Then, we state the following:

(iv) No country is better-off when free-riding: $v_{j\in G}(X_G, x_j, t_j) \geq \theta_j(X_{G-j}), \forall j$.

Note that (iv) is a stricter version of (i). If there is a coalition G that holds with (iv) for all countries, then coalition G is internally stable (hereafter stable) - i.e. no country has an incentive to withdraw from the coalition.[13] In consequence, the coalition G constitutes a Nash equilibrium and the NAMAs portfolio is self-enforcing.[14] We have two situations when analyzing anti free-rider incentives: one for pivotal countries and other for non-pivotal countries.

Proposition 1. *If (i) to (iii) are fulfilled, and j is pivotal, then (iv) always holds for country j.*

Proof. If country j is a pivotal DCs, and it leaves the coalition G, then the NAMAs portfolio is not implemented at all and its final payoff from free-riding is zero, and by (i) $v_{j\in G}(X_G, x_j, t_j) \geq 0$, (iv) (weakly) holds and j has no incentives to free-ride. ■

Proposition 1 implies that (i) is necessary and sufficient for pivotal countries. However, if j is a non-pivotal DCs, j decides to take part in the coalition if and only if it satisfies (iv). Therefore, if we have a feasible set $\{\vec{X}, \vec{T}\}$ which holds with (ii) and (iv) for all i, then coalition G is balanced, individually rational, avoids free-rider incentives and by consequence is efficient at providing the public good - i.e., X_G is provided.

If (iv) does not hold for a non-pivotal country j, the Nash equilibrium is that j free-rides and the NAMAs portfolio is carried out by coalition $G - j$. This result is in line with that found by Nagashima et al. (2009). They study the impact of transfer on the incentives for regions to join international climate agreements. They find that no transfer is capable of stabilizing the participation of all countries, but an optimal sharing surplus rule proposed by Weikard

[13] In this paper, we only search for internally stable coalitions as G is the grand coalition. However, in related studies, the externally stable concept is also employed: a coalition is externally stable if no non-participating country has an incentive to joint the coalition (d'Aspremont et al., 1983; Nagashima et al., 2009).

[14] We do not consider (iv) for developed countries as their participation is mandatory in NAMAs.

(2009) allows the formation of larger stable coalitions which include key players. Therefore, in section 3.3.2, we test the transfer *à la Weikard* to the case of NAMAs.

Asymmetric information

Asymmetric informational problems have been reported in the contract design of payments for environmental services (Ferraro, 2008). There are two important information asymmetries in the design of contracts: hidden information (i.e., adverse selection) and hidden action (i.e., moral hazard).[15] Labbate (2008) analyzes adverse selection problems in the application of the Incremental Costs (IC) principle for the conservation of global habitats by the GEF.[16] As the calculation of the IC requires the estimation of benefits and costs in two distinct scenarios (baseline and counterfactual), there are incentives to the recipient countries to misrepresent their costs and benefits from the project, and therefore receive higher IC transfers.

For the case of global climate policy, asymmetric informational problems have been studied in joint implementation (Hagem, 1996) and CDM projects (Millock, 2002). Hagem (1996) considers that countries may have two kinds of private information on efficiency, and on actions taken during the project period. Millock (2002) considers that Non-Annex I countries possess private information on a technical efficiency parameter (i.e., they may exaggerate their emission reduction costs in order to receive a larger transfer).

In this context, for the case of NAMAs, the initial payoff of countries $\widehat{v}_{j\in G}$ may not be observable or available public information since each country should know their costs better than the others $c_j(x_j)$ and benefits $\theta_j(X_G)$ associated with the implementation of a NAMAs portfolio. Then, countries may misrepresent their types by either overestimating costs $\widetilde{c}_j(x_j)$ or underestimating benefits $\widetilde{\theta}_j(X_G)$, and in consequence they may get an "informational rent". Thus, we state the following *incentive compatibility condition* for NAMAs:

(v) No country misrepresents its type if: $v_{j\in G}(X_G, x_j, t_j) \geq v_{j\in G}(X_G, x_j, \widetilde{t}_j) \forall j$.

[15] For a comprehensive theoretical framework on asymmetric information, see, for example, Bolton and Dewatripont (2005).

[16] IC is the extra cost that a country incurs when contributing to a global public good in an amount greater than it would have contributed if it had been guided solely by criteria of national interest. The country that undertakes the extra effort receives a compensation payment (King, 2006)).

With some abuse of the notation in (v), we let $\widetilde{t}_j$ be the transfer that country j makes when it announces either $\widetilde{\theta}_j(X_G)$ or $\widetilde{c}_j(x_j)$.

Finally, an ideal contract for the implementation of a NAMAs portfolio has to guarantee five requirements: it is individually rational, condition (i); it is budget-balanced, condition (ii); it is feasible, condition (iii); it avoids free-riding, condition (iv); and it is incentive compatible, condition (v). An important role in such a contract is played by the transfer schemes employed to implement the NAMAs portfolio. Therefore, we focus in the next section on transfer schemes for NAMAs.

3.3 Transfer schemes for NAMAs

Transfers have recently attracted the attention of the literature on global climate agreements since they are seen as efficient instruments to target climate change directly. They have been mainly associated with the flow of resources from developed countries to DCs (Frankel, 2007; Höhne et al., 2006; Reinstein, 2004; Sugiyama and Sinton, 2005). Rose et al. (1998) investigate the impact of transfers for allocating emissions permits. They classify transfers into two types: allocation-based rules, i.e., permits are initially distributed among countries according to certain criteria, and outcome-based rules, i.e., net benefits from cooperative abatement efforts are distributed among countries based on certain criteria. More recently, Nagashima (2010) summarizes, in-depth, the alternative transfers employed in the literature to tackle global climate policies as well as the main results found due to their implementation. She points out that the design and analysis of transfers among countries in the form of side payments, emissions permit trading or surplus sharing has been mainly focused on one particular issue, namely the curtailing of free-rider incentives. For our analysis, we consider it appropriate to state the following set of definitions.

Definition 3. *A transfer for NAMAs $t_i(X_G, x_i)$ is a sharing rule of distributing the total initial payoff $\sum_{i=1}^{I} \widehat{v}_{i \in G}(X_G, x_i)$ of countries $i \in G$ such that conditions (i) and (ii) are fulfilled.*

Definition 4. *The transfer $t_i(X_G, x_i)$ provides an anti-free-rider incentive and it is considered as efficient if it allows (iv) to be fulfilled $\forall i \in G$, in consequence $\vec{X}_G$ is reached.*

A transfer that deals with asymmetric informational problems is considered as a *mechanism* by the literature of *mechanism design problem* (Mas-Colell et al., 1995). Therefore, in order to continue with this well-established definition, we consider it necessary to make the difference between a *transfer* and a *mechanism*.

Definition 5. *A transfer for NAMAs $t_i(X_G, x_i)$ is a* mechanism *if and only if it is efficient and it allows (v) to be fulfilled.*

Definition 5 states, then, that the main goal of a *mechanism* is to deal with asymmetric information. A *mechanism* may be viewed as an *institution* or a *center* which governs the procedure for making the collective choice. This *center* is completely informed about the type that each country is and it has the possibility to "arrange" the game so that countries receive the best final payoff when telling the truth.

Armed with these definitions, an ideal transfer for NAMAs would be a *mechanism* that meets conditions (i) to (v). However, we know by the **Myerson-Sattertwhaite** impossibility theorem (Myerson and Sattertwhaite, 1983) that, in general, there is not a *mechanism* that is individually rational, condition (i); it is budget-balanced, condition (ii); it makes possible the provision of a public good, condition (iii); and it avoids misrepresentation, condition (v) when participation is voluntary. Moreover, Emons (1994) shows, for example, that the set of conditions (i) to (iii) do not always hold simultaneously for the well-known *mechanisms* employed for the provision of a public good under private information, namely, the *Clarke-Groves* and the *d'Aspremont-Gérard-Varet* mechanisms. He observes that *Clarke-Groves* transfers are not budget-balanced (i.e., the sum of transfers is negative). This failure may be avoided by the *d'Aspremont-Gérard-Varet* transfer; however, in this one, participation of some agents may not be individually rational.

Transfers under the *Clarke-Groves mechanism* depend on the effect that countries impose on the coalition with its participation (Clarke, 1971; Groves, 1973). For the case of a NAMAs portfolio, the *Clarke-Groves mechanism* may be stated as $t_i^{CG}(\cdot) = \sum_{j=1, j\neq i}^{I} \widehat{v}_{j\in G}$ $(X_{G-i}, x_j) - \sum_{j=1, j\neq i}^{I} \widehat{v}_{j\in G}(X_G, x_j)$. Looking on the right-hand side, the first term represents the effect that country i imposes to all other countries in the coalition when it does not participate, and the second term is the effect that i imposes to all other countries with its participation. Under this transfer scheme, i's transfer is zero if when it reveals its type, it does not change the decision of providing the public good (e.g., NAMAs). Otherwise, it receives a transfer, and in that case i is pivotal for the provision of the public good. Thus, the sum of transfers is obviously negative. Several studies have shown that the *Clarke-Groves mechanism* is not budget-balanced, see for instance, Emons (1994). As a result, it is not a transfer for NAMAs, as we state in definition 3.

Under the *d'Aspremont-Gérard-Varet mechanism*, a country's transfer is based on the expected value of the other countries' initial payoffs depending on its own (d'Aspremont and Gérard-Varet, 1979). It may be denoted for NAMAs as $t_i^{AGV}(\cdot) = \xi_i\left[\widetilde{\widehat{v}}_i(\cdot), \widehat{v}_j(\cdot)\right] - \frac{1}{(I-1)}\sum_{j=1}^{I}\xi_{j\neq i}\left[\widetilde{\widehat{v}}_j(\cdot), \widehat{v}_i(\cdot)\right]$.[17] This *mechanism* assumes that the parameter containing private information, in our case $\widehat{v}_i(\cdot)$ is not known by country i before participation. Looking on the right hand side, the first term represents the sum of j's expected payoff when country i announces a $\widetilde{\widehat{v}}_i(\cdot)$; and the second term is a contribution that country i makes to each other $I-i$ country when it states the truth.

This mechanism is budget-balanced since $\sum_{i=1}^{I} t_i^{AGV}(\cdot) = \sum_{i=1}^{I}\xi_i[\cdot] - \frac{1}{(I-1)}\sum_{i=1}^{I}(I-1)\xi_i[\cdot] = 0$. However, under this mechanism, it is possible that some countries have to pay a $t_i^{AGV} > \widehat{v}_i(\cdot)$. Thus, if these countries know in advance their types $\widehat{v}_i(\cdot)$ but they do not know the other agents' types, they will not have an incentive to participate when they are obligated to state the truth, since substituting the *d'Aspremont-Gérard-Varet* transfer in (3.1), we conclude by condition (i), $v_i(X_G, x_i, t_i^{AGV}) < 0$. Thus, the *d'Aspremont-Gérard-Varet* is not a transfer for NAMAs, as we state in definition 3.

We have just shown that even when condition (iii) holds, conditions (i) and (ii) are not necessarily fulfilled. Therefore, as these time-honored mechanisms employed for the provision of a public good do not meet the minimal requirements for the implementation of a NAMAs portfolio, we restrict thereafter our attention only to transfers that meet definition 3. Then, we check their efficiency in the provision of NAMAs (definition 4) to see whether they could be employed as mechanisms (definition 5). We particularly analyze NAMAs under two alternative transfers: a *horizontal equity-based* transfer and a transfer *à la Weikard*.

[17] ξ_i is an expectational term. For a mathematical explanation of its meaning, see Mas-Colell et al. (1995), page 886.

Although both transfers are of the type of surplus sharing, they differ in that the *horizontal equity-based* transfer distributes the surplus payoff following an egalitarian rule (i.e., every participating country receives the same final payoff from avoiding GHG emissions); and the transfer *à la Weikard* shares the surplus payoff in order to compensate the countries' outside payoffs (i.e., when free-riding). Furthermore, they differ in that the *horizontal equity-based* transfer is a pragmatic transfer in the sense that it is the simplest way to distribute the surplus payoff, whereas the transfer *à la Weikard* is a more elaborated transfer and it is considered to be an "optimal sharing rule".

3.3.1 A horizontal equity-based transfer scheme

We propose the following *horizontal equity-based* transfer scheme for NAMAs:

$$t_j^H(X_G,x_i) = \widehat{v}_{j\in G}(X_G,x_i) - \frac{\sum_{i=1}^{I}\widehat{v}_{i\in G}(X_G,x_i)}{I}. \tag{3.4}$$

This transfer follows a distribution rule for the surplus payoff that allows all participating countries to receive an equalized final payoff. This *horizontal equity-based* transfer follows the idea of the horizontal outcome-based equity criterion for global climate policy described by Rose et al. (1998). They define this criterion for the distribution of tradable CO_2 emission permits, where all countries are treated equally. Its main operational rule is to equalize net welfare change across nations.

Proposition 2. *If (iii) holds and $\vec{T}$ follows (3.4), then (ii) and (i) also hold.*

Proof. For (ii), substituting (3.4) in (ii), we see:
$\sum_{i=1}^{I} t_i^H(X_G,x_i) = \sum_{i=1}^{I}\left[\widehat{v}_{i\in G}(X_G,x_i) - \frac{\sum_{j=1}^{I}\widehat{v}_{j\in G}(X_G,x_j)}{I}\right] = 0.$
For (i), the final payoff of country i when it takes part in the grand coalition G may be calculated substituting (3.4) in (3.1). That is:

$$v_{i\in G}(X_G,x_i,t_i^H) = \frac{\sum_{i=1}^{I}\widehat{v}_{i\in G}(X_G,x_i)}{I} = \frac{\Theta_G(X_G)-C_G(\vec{X}_G)}{I} \geq 0, \text{ by (iii).}$$

■

We analyze free-rider incentives under this *horizontal equity-based* transfer (3.4) for a non-pivotal country j when conditions (i) to (iii) hold. Substituting (3.4) in (3.1), we can rewrite (iv) as follows:

$$\frac{\Theta_G(X_G) - C_G(\vec{X}_G)}{I} \geq \theta_j(X_{G-j}). \tag{3.5}$$

From (3.5) we state that a non-pivotal country j which receives lower environmental gains from the mitigation of other coalition members than the average initial payoffs has an incentive to remain in the grand coalition. Otherwise, j free-rides and coalition $G-j$ is formed.

Now consider misrepresentation incentives for country j. As analyzed in section 3.2.2, countries may misrepresent $\widehat{v}_{j\in G}(X_G, x_j)$. Then, if country j overestimates mitigation costs by announcing a $\widetilde{c}_j(x_j) > c_j(x_j)$, then (3.4) becomes:

$$\widetilde{t}_j^H(X_G, x_j) = \theta_j(X_G) - \widetilde{c}_j(x_j) - \frac{\Theta_G(X_G) - C_{G-j}(\vec{X}_{G-j}) - \widetilde{c}_j(x_i)}{I}. \tag{3.6}$$

We find, by rewriting (v), that this country will not have incentives to misrepresent its type if $v_{j\in G}(X_G, x_j, t_j^H) - v_{j\in G}(X_G, x_j, \widetilde{t}_j^H) \geq 0$. We rewrite the final payoff of country j if it tells the truth as $\frac{\Theta_G(X_G) - C_{G-j}(\vec{X}_{G-j}) - c_j(x_j)}{I}$ (see proof of proposition 2); and by substituting (3.6) in (3.1), we find that the final payoff of country j when it announces $\widetilde{c}_j(x_j)$ is $\widetilde{c}_j(x_j) - c_j(x_j) + \frac{\Theta_G(X_G) - C_{G-j}(\vec{X}_{G-j}) - \widetilde{c}_j(x_j)}{I}$. Then, $v_{j\in G}(X_G, x_j, t_j^H) - v_{j\in G}(X_G, x_j, \widetilde{t}_j^H) = \left[\widetilde{c}_j(x_j) - c_j(x_j)\right]\frac{1-I}{I} < 0$. As a result, country j has an interest to overstate its mitigation costs.

The same analysis may be done when j understates its benefits by announcing $\widetilde{\theta}_i(X_G) < \theta_i(X_G)$. There, (3.4) becomes:

$$\widetilde{t}_j^H(X_G, x_j) = \widetilde{\theta}_j(X_G) - c_j(x_j) - \frac{\Theta_{G-j}(X_G) + \widetilde{\theta}_j(X_G) - C_G(\vec{X}_G)}{I}. \tag{3.7}$$

We rewrite the final payoff of country j when stating the truth as $\frac{\Theta_{G-j}(X_G) + \theta_j(X_G) - C_G(\vec{X}_G)}{I}$. Substituting (3.7) in (3.1), we find that the final payoff of country j when misrepresenting its environmental gain is $\theta_j(X_G) - \widetilde{\theta}_j(X_G) + \frac{\Theta_{G-j}(X_G)+\widetilde{\theta}_j(X_G)-C_G(\vec{X}_G)}{I}$. Then:

$$\begin{aligned} v_{j\in G}(X_G, x_j, t_j^H) - v_{j\in G}(X_G, x_j, \widetilde{t}_i^H) &= \frac{\theta_j(X_G) - \widetilde{\theta}_j(X_G)}{I} - \theta_j(X_G) + \widetilde{\theta}_j(X_G) \\ &= \frac{1-I}{I}\left[\theta_j(X_G) - \widetilde{\theta}_j(X_G)\right] < 0. \end{aligned}$$

Again, country j gains from misreporting its type.

In summary, the *horizontal equity-based* transfer scheme is individually rational and balanced. However, it does not avoid free-riding for all types of countries, preventing the formation of the grand coalition and in consequence not reaching the coalitional target X_G. Thus, it is not efficient. Moreover, it is not incentive compatible, since coalition members are better-off either over-reporting their mitigation costs or understating their environmental benefits, and as a result it may not be considered as a mechanism (definition 5).

3.3.2 An "optimal" transfer scheme à la Weikard

Nagashima et al. (2009) found that an optimal sharing surplus transfer was the best at avoiding free-rider incentives and stabilizing climate coalitions. Optimal sharing surplus transfers have been suggested by Carraro et al. (2006); McGinty (2007); Weikard (2009); Fuentes-Albero and Rubio (2010). In this paper, we consider the implementation of NAMAs based on Weikard (2009). Thus, we establish the following transfer *à la Weikard*:[18]

$$t_j^W\ (X_G, x_j) = \widehat{v}_{j\in G}(X_G, x_j) - \frac{\theta_j(X_{G-j})}{\sum_{k=1}^I \theta_k(X_{G-k})} \times \sum_{i=1}^I \widehat{v}_{i\in G}(X_G, x_i). \tag{3.8}$$

Weikard (2009) proposes to share the surplus payoff following a rule where the coalition surplus is distributed proportional to outside option payoffs (See equation 3.3). The term $\sum_{k=1}^I \theta_k(X_{G-k})$ is the total of outside option payoffs. Weikard transfers more benefit to countries with the highest outside option payoff.

[18] We have changed the order of terms in the original formula with the aim of aligning it with the meaning of the sign we employ in our model: $t_i(\cdot) > 0$, country i contributes to finance NAMAs abroad, otherwise it is a transfer recipient.

Proposition 3. *If (iii) holds and $\vec{T}$ follows (3.8), then (ii) and (i) also hold.*

Proof. For (ii), substituting (3.8) in (ii), we see:

$$\begin{aligned}\sum_{j=1}^{I} t_j^W\ (X_G, x_j) &= \sum_{j=1}^{I}\left[\widehat{v}_{j\in G}(X_G, x_j) - \frac{\theta_j(X_{G-j})}{\sum_{k=1}^{I}\theta_k(X_{G-k})} \times \sum_{i=1}^{I}\widehat{v}_{i\in G}(X_G, x_i)\right] \\ &= \sum_{i=1}^{I}\widehat{v}_{i\in G}(X_G, x_i) - \frac{\sum_{j=1}^{I}\theta_j(X_{G-j})}{\sum_{k=1}^{I}\theta_k(X_{G-k})} \times \sum_{i=1}^{I}\widehat{v}_{i\in G}(X_G, x_i) = 0.\end{aligned}$$

For (i), the final payoff of country j when it takes part in the grand coalition G may be calculated substituting (3.8) in (3.1):

$$\begin{aligned}v_j(X_G, x_j, t_j^W) &= \widehat{v}_{j\in G}(X_G, x_j) - t_j^W\ (X_G, X_{G-j}, x_j) \\ &= \sum_{i=1}^{I}\widehat{v}_{i\in G}(X_G, x_i) \times \frac{\theta_j(X_{G-j})}{\sum_{k=1}^{I}\theta_k(X_{G-k})} \\ &= \left[\Theta(X_G) - C_G(\vec{X}_G)\right] \times \frac{\theta_j(X_{G-j})}{\sum_{k=1}^{I}\theta_k(X_{G-k})} \geq 0.\end{aligned}$$

If $\Theta_G(X_G) = C_G(\vec{X}_G)$, then $v_j(X_G, x_j, t_j^W) = 0$. For the case when $\Theta_G(X_G) > C_G(\vec{X}_G)$; pivotal countries have $\theta_j(X_{G-j}) = 0$, by proposition 1, and they then receive a final payoff $v_j(X_G, x_j, t_j^W) = 0$; and non-pivotal countries receive $v_j(X_G, x_j, t_j^W) > 0$ as a final payoff. ∎

Now consider free-rider incentives for non-pivotal countries under the transfer *à la Weikard*. We can rewrite (iv), by substituting (3.8) in (3.1), as follows:

$$\left[\Theta_G(X_G) - C(\vec{X}_G)\right] \times \frac{\theta_j(X_{G-j})}{\sum_{k=1}^{I}\theta_k(X_{G-k})} \geq \theta_j(X_{G-j}), \tag{3.9}$$

which is the same as:

$$\Theta_G(X_G) - C(\vec{X}_G) \geq \sum_{k=1}^{I} \theta_k(X_{G-k}). \tag{3.10}$$

As proved above, if (ii) holds for (3.8), then pivotal countries pay a transfer equivalent to $t_j^W(X_G, x_j) = \widehat{v}_{j\in G}(X_G, x_j)$, and all surplus payoff, if any, is allocated to non-pivotal countries. From (3.9) or (3.10), we conclude that when the surplus payoff exceeds or equals the total of outside option payoffs of non-pivotal countries, no non-pivotal country k has an incentive to free-ride, and the grand coalition formed is stable. When (3.10) holds, Weikard (2009) states that the coalition G is potentially self-enforcing (stable).

We analyze whether when G is formed with transfers *à la Weikard*, signatory countries would have incentives to misrepresent their types. They can do this by overstating their mitigation costs or understimating their environmental gains. For notational ease, we define $b_j = \left(\frac{\theta_j(X_{G-j})}{\sum_{k=1}^{I}\theta_k(X_{G-k})}\right)$. Country j would misrepresent its type by, for instance, over-reporting its mitigation costs $\widetilde{c}_j(x_j) > c_j(x_j)$,[19] then (3.8) becomes:

$$\widetilde{t}_j^W\ (X_G, x_j) = \theta_j(X_G) - \widetilde{c}_j(x_j) - \left[\Theta_G(X_G) - C_{G-j}(\vec{X}_{G-j}) - \widetilde{c}_j(x_j)\right] b_j. \tag{3.11}$$

Substituting (3.11) in (3.1), we find that the final payoff of country j when over-reporting its mitigation costs is $\widetilde{c}_j(x_j) - c_j(x_j) + b_j\left[\Theta_G(X_G) - C_{G-j}(\vec{X}_{G-j}) - \widetilde{c}_j(x_j)\right]$. Then, the incentive compatibility condition (v) does not hold as $v_{j\in G}(X_G, x_j, t_j^W) - v_{j\in G}$ $(X_G, x_j, \widetilde{t}_j^W) = \left[c_j(x_j) - \widetilde{c}_j(x_j)\right](1 - b_j) < 0$. Note that $0 \leq b_j \leq 1$. If $b_j = 0$, then j is pivotal and if $b_j = 1$, then there is only one country and it is non-pivotal. Therefore, country j has an interest to overstate its mitigation costs.

When country j under-reports its environmental gain $\widetilde{\theta}_j(X_G) < \theta_j(X_G)$, (3.8) becomes:[20]

$$\widetilde{t}_j^W\ (X_G, x_j) = \widetilde{\theta}_j(X_G) - c_j(x_j) - \left[\Theta_{G-j}(X_G) + \widetilde{\theta}_j(X_G) - C_G(\vec{X}_G)\right] b_j. \tag{3.12}$$

Substituting (3.12) in (3.1), we deduce that the final payoff of country j when it announces $\widetilde{\theta}_j(X_G)$ is $\theta_j(X_G) - \widetilde{\theta}_j(X_G) + \left[\Theta_{G-j}(X_G) + \widetilde{\theta}_j(X_G) - C_G(\vec{X}_G)\right] b_j$. Then, the incentive compatibility condition (v) does not hold as $v_{j\in G}(X_G, x_j, t_j^W) - v_{j\in G}(X_G, x_j, \widetilde{t}_j^W)$

[19] We do not analyze $\widetilde{c}_j(x_j)$ if j is a developed country since it does not incur any mitigation costs.

[20] In this study, we do not consider the possibility that country j does misrepresent its type $\theta_j(X_{G-j})$.

$= \left[\widetilde{\theta}_j(X_G) - \theta_j(X_G)\right](1-b_j) < 0$. Once more, country j gains from misreporting.

In conclusion, the transfer scheme *à la Weikard* is balanced, individually rational and allows the formation of the grand coalition if the surplus payoff covers the total of outside option payoffs of non-pivotal countries. Thus, it is efficient at providing the public good, X_G. However it is not incentive compatible because countries may misrepresent their true types; consequently it may not be defined as a mechanism (definition 5).

3.4 NAMAs under an illustrative example

In this section, we describe NAMAs through an illustrative example. We analyze the case of full cooperation as well as free-riding and misrepresentation problems for both the *horizontal equity-based* and the transfer *à la Weikard*. Consider the negotiation of a NAMAs portfolio by four countries $I = \{A, B, C, D\}$. Country A is a developed country. Countries B, C and D are Non-Annex I countries. They are different in three points, namely: the income measured through the GDP$_i$, GHG emission reduction x_i, and marginal abatement costs $c\prime_i$ of reducing GHG emissions. Countries have linear abatement costs, so that $c_i(x_i) = c\prime_i x_i$. We assume that the following inequalities hold for these Non-Annex I countries: GDP$_B >$ GDP$_C >$ GDP$_D, x_B > x_C > x_D$, and $c\prime_B < c\prime_C < c\prime_D$. For simplicity, we consider that the GHG emission reduction target is $X_G = 20$ units, with $X_G = x_b + x_c + x_d$.

We estimate damages which are avoided by reducing these 20 units as an arbitrary proportion of GDP$_i$, i.e., $\theta_i(X_G) = \theta_i(20) = \frac{1}{9}GDP_i$. As θ_i is increasing in X, then $\theta_i(X_G) > \theta_i(X_{G-c}) > \theta_i(X_{G-d})$, where $X_{G-i} = X_G - x_i$ for $i = C, D$. Let us choose a set $\{\vec{X}, \vec{T}\}$ which satisfies these properties: (a) that condition (iii) holds; (b) that country B carries out a unilateral NAMAs program as $\theta_i(X) > c_i(x_i)$; (c) that country C undertakes a partially supported NAMAs as $\theta_i(X) < c_i(x_i)$; (d) that country D embarks on a *quasi* fully supported NAMAs as $\theta_i(X) << c_i(x_i)$; and (e) that countries A & B are pivotal. Table 3.1 shows a set of values (x_i, GDP$_i, c\prime_i$) that satisfy all these assumptions. Remember that $\widehat{v}_i(X_G, x_i) = \theta_i(X_G) - c_i(x_i)$, and it is the initial payoff of country i.

Table 3.1: Data for the illustrative example.[a]

Parameter	Country A	Country B	Country C	Country D	Total
GDP_i	320.00	225.00	45.00	5.00	595.00
x_i	[b]	10.44	8.00	1.56	20.00
$c\prime_i$	[b]	2.00	4.00	6.00	-
$c_i(x_i)$	[b]	20.88	32.00	9.33	62.22
$\theta_i(X_G)$	35.55	25.00	5.00	0.55	66.11
$\widehat{v}_i(X_G, x_i)$	35.55	4.12	-27.00	-8.78	3.89
$\theta_i(X_{G-c})$[c]	18.82	13.24	2.65	0.29	32.35
$\theta_i(X_{G-d})$[d]	33.68	23.68	4.74	0.53	62.11

[a] All figures are given in the same numeration (u).
[b] As country A is a developed country, these values are not needed for our calculation.
[c] We assign $\theta_i(12) = (1/17)\text{GDP}_i$.
[d] We assign $\theta_i(18.44) = (1/9.5)\text{GDP}_i$.

3.4.1 The horizontal equity-based transfer scheme

We apply to this feasible set the *horizontal equity-based* transfer. Table 3.2 shows the results for full cooperation, free-riding and misrepresentation that we analyze in section 3.3.1. Note that proposition 2 holds since the total sum of transfers is zero (ii), and that transfers guarantee that every country receives a positive final payoff (i). The surplus payoff is distributed in an egalitarian way. Countries A & B pay for NAMAs in other countries, whereas countries C & D receive transfers to undertake their NAMAs.

When we consider anti free-rider incentives, we have the following results: (a) that pivotal countries A & B do not have incentives to free-ride as their outside payoffs are zero (proposition 1); (b) that coalition G formed by the four countries is not internally stable, as country C is better-off outside; (c) that the only stable coalition is that which is formed by countries A, B & D because no-country (i.e., A, B & D) is better-off outside (internal stability), and no outside country (i.e., C) is better-off rejoining the coalition (external stability). Remember that for non-pivotal countries (iv) is $\frac{\sum_{i=1}^{I} \widehat{v}_i(X_G, x_i)}{I} = 0.97 \geq \theta_j(X_{G-j})$. In this example the only country with an outside payoff greater than the average initial payoff is country C, that is $\theta_c(X_{G-c}) = 2.65 > 0.97$.

Table 3.2: *Horizontal equity-based* transfer applied to illustrative example.[a]

Parameter	Country A	Country B	Country C	Country D	Total
Full cooperation					
$t_i(X_G, x_i)$	34.58	3.14	-27.97	-9.75	0.00
$v_{i\in G}(X_G, x_i, t_i)$	0.97	0.97	0.97	0.97	3.89
Country C free-rides, $X_{G-c} = 12.00$					
$t_i(X_{G-c}, x_i)$	18.11	-8.36	-	-9.75	0.00
$v_{i\in G}(X_{G-c}, x_i, t_i)$	0.71	0.71	(2.65)[b]	0.71	2.13
Country D free-rides, $X_{G-d} = 18.44$					
$t_i(X_{G-d}, x_i)$	30.61	-0.28	-30.34	-	0.00
$v_{i\in G}(X_{G-d}, x_i, t_i)$	3.07	3.07	3.07	(0.52)[b]	9.22
Country D leaves the coalition G^*, $X_{G^*} = 10.44$[c]					
$\theta_i(X_{G^*}, x_i)$	17.78	12.50	-	0.28[c]	30.27
$t_i(X_{G^*}, x_i)$	13.08	-13.08	-	0.00	0.00
$v_{i\in G}(X_{G^*}, x_i, t_i)$	4.69	4.69	-	(0.28)[b]	9.39
Country A announces $\widetilde{\theta}_A(X_{G^*}) = 18.00$					
$t_i(X_{G-c}, x_i)$	(17.56)[d]	-8.09	-	-9.47	0.00
$v_{i\in G}\left[(X_{G-c}, x_i, t_i), \widetilde{t}_A\right]$	1.26	0.44	-	0.44	2.13
Country B announces $\widetilde{\theta}_B(X_{G^*}) = 13.00$					
$t_i(X_{G-c}, x_i)$	18.19	(-8.52)[f]	-	-9.67	0.00
$v_{i\in G}\left[(X_{G-c}, x_i, t_i), \widetilde{t}_B\right]$	0.63	0.87	-	0.63	2.13
Country B announces $\widetilde{c}_B(x_B) = 22.00$					
$t_i(X_{G-c}, x_i)$	18.48	-9.10	-	-9.38	0.00
$v_{i\in G}\left[(X_{G-c}, x_i, t_i), \widetilde{t}_B\right]$	0.34	1.45	-	0.34	2.13
Country D announces $\widetilde{\theta}_D(X_{G^*}) = 0.10$					
$t_i(X_{G-c}, x_i)$	18.18	-8.30	-	(-9.88)[d]	0.00
$v_{i\in G}\left[(X_{G-c}, x_i, t_i), \widetilde{t}_D\right]$	0.65	0.65	-	0.84	2.13
Country D announces $\widetilde{c}_D(x_D) = 10.00$					
$t_i(X_{G-c}, x_i)$	18.34	-8.14	-	-10.19	0.00
$v_{i\in G}\left[(X_{G-c}, x_i, t_i), \widetilde{t}_D\right]$	0.49	0.49	-	1.15	2.13

[a] All figures are given in the same numeration (u).
[b] These values are not included in the total column. Furthermore, they correspond to $\theta_i(X_{G-i})$.
[c] We assign $\theta_i(10.44) = (1/18)\text{GDP}_i$.
[d] This value corresponds to $\widetilde{t}_i(X_{G^*}, x_i)$.

We retain the stable coalition $G^* = \{A, B, D\}$. Its payoffs and transfer schemes are those of the second set in table 3.2. We analyze misrepresentation of mitigation costs and the willingness to pay parameters for countries belonging to the stable coalition when they announce a $\widetilde{c}_j(x_j) > c_j(x_j)$ or a $\widetilde{\theta}_j(X_{G^*}) < \theta_j(X_{G^*})$. We conclude that they always have incentives to deviate from the truth when the other countries state the truth. Finally, the best outcome of the game under the *horizontal equity-based* transfer is a Nash equilibrium characterized by this: countries A, B & D embark in a NAMAs coalition (i.e., they sign the NAMAs contract), and every country is better-off if country C remains as a free-rider.

3.4.2 The transfer à la Weikard

In this section, we apply the transfer *à la Weikard* to the feasible set $\{\vec{X}, \vec{T}\}$ presented in table 3.1. Table 3.3 shows the results for full cooperation and misrepresentation which we analyze in section 3.3.2.[21] Proposition 3 holds since this transfer always allows the implementation of a budget-balanced NAMAs portfolio (ii) and countries receive zero or positive payoffs (i). Note that the surplus payoff is the same as under the *horizontal equity-based* transfer. However, transfers *à la Weikard* redistribute initial payoffs of countries to those countries which have the higher outside payoffs, the non-pivotal countries C & D. All transfers paid by pivotal countries are allocated to non-pivotal countries. As a result, pivotal countries receive zero as their final payoff. We discover that the NAMAs coalition G formed by all countries is stable (i.e., the grand coalition). No country has an incentive to leave. This result shows that this transfer scheme is better than the *horizontal equity-based* transfer scheme. However, as for the *horizontal equity-based* transfer scheme, every country is better-off misrepresenting its type, either underestimating its environmental gain or over-reporting its mitigation costs.

[21] See $\theta_j(\cdot)$ values when free-riding in table 3.2.

Table 3.3: Transfer *à la Weikard* applied to illustrative example.[a]

Parameter	Country A	Country B	Country C	Country D	Total
Full cooperation					
$t_i\ (X_G, x_i)$	35.56	4.11	-30.24	-9.42	0.00
$v_i(X_G, x_i, t_i)$	0.00	0.00	3.24	0.64	3.89
Country A announces $\widetilde{\theta}_A(20) = 35.00$					
$t_i(X_G, x_i)$	35.00	4.11	-29.78	-9.33	0.00
$v_i\left[(X_G, x_i, t_i), \widetilde{t}_A\right]$	0.56	0.00	2.78	0.55	3.89
Country B announces $\widetilde{\theta}_B(20) = 24.00$					
$t_i(X_G, x_i)$	35.56	3.11	-29.41	-9.26	0.00
$v_i\left[(X_G, x_i, t_i), \widetilde{t}_B\right]$	0.00	1.00	2.41	0.48	3.89
Country B announces $\widetilde{c}_B(x_B) = 22.00$					
$t_i(X_G, x_i)$	35.56	3.00	-29.32	-9.24	0.00
$v_i\left[(X_G, x_i, t_i), \widetilde{t}_B\right]$	0.00	1.12	2.32	0.46	3.89
Country C announces $\widetilde{\theta}_C(20) = 4.50$					
$t_i(X_G, x_i)$	35.56	4.11	-30.33	-9.34	0.00
$v_i\left[(X_G, x_i, t_i), \widetilde{t}_C\right]$	0.00	0.00	3.33	0.56	3.89
Country C announces $\widetilde{c}_C(x_c) = 33.00$					
$t_i(X_G, x_i)$	35.56	4.11	-30.41	-9.26	0.00
$v_i\left[(X_G, x_i, t_i), \widetilde{t}_C\right]$	0.00	0.00	3.41	0.48	3.89
Country D announces $\widetilde{\theta}_D(20) = 0.45$					
$t_i(X_G, x_i)$	35.56	4.11	-30.16	-9.51	0.00
$v_i\left[(X_G, x_i, t_i), \widetilde{t}_D\right]$	0.00	0.00	3.16	0.73	3.89
Country D announces $\widetilde{c}_D(x_D) = 10.00$					
$t_i(X_G, x_i)$	35.56	4.11	-29.69	-9.98	0.00
$v_i\left[(X_G, x_i, t_i), \widetilde{t}_D\right]$	0.00	0.00	2.69	1.20	3.89

[a] All figures are given in the same numeration (u).

3.5 Policy implications and concluding remarks

In this paper, we envisage the implementation of a NAMAs portfolio by means of two transfer schemes: a *horizontal equity-based* and an "optimal" transfer which we call *à la Weikard*. We model NAMAs as a non-cooperative, one shot game. We then find the following results.

First, these transfer schemes may allow the implementation of a NAMAs coalition which is balanced and individually rational. That is, if NAMAs occur, then these transfer schemes ensure that no country will receive a negative final payoff and that the sum of transfers among countries is zero. The latter feature guarantees that there is no need for external source of funds to finance NAMAs. Therefore, these transfers make of NAMAs a "self-financing" climate policy instrument.

Secondly, concerning free-rider incentives, we have two main findings. On the one hand, NAMAs is "self-enforcing" for countries which are pivotal for the NAMAs portfolio regardless of the transfer scheme employed. This result entails one main policy implication: if the definition of a pivotal country is taken into account in the design of NAMAs, then pivotal countries are the most interested in the realization of NAMAs, even if they pay the highest transfers. Thus, "no-action" is not a credible threat for pivotal countries, as would usually be thought. Nevertheless, we consider that more research has to be undertaken to elucidate the role of pivotal countries in global climate policies. On the other hand, the transfer *à la Weikard* allows the implementation of a self-enforcing NAMAs coalition, also for all non-pivotal countries if the eventual surplus payoff covers the total outside payoff options of these countries. Nevertheless, in this regard, the *horizontal equity-based* transfer does not avoid free-riding for non-pivotal countries with outside payoffs larger than the average initial payoffs. Obtaining a self-enforcing NAMAs coalition facilitates international MRV both for funding and GHG reductions.

Thirdly, these transfer schemes do not avoid asymmetric informational problems when countries misrepresent either their mitigation costs or environmental gains from the NAMAs portfolio. This result is in line with the **Myerson-Sattertwhaite** impossibility theorem: there is not, in general, a mechanism (i.e., transfer) that it is efficient, balanced, individually rational and incentive compatible (i.e., that avoids asymmetric information). Therefore, policy makers, depending on their priorities, have to choose between mechanisms for avoiding asymmetric information and transfers that are efficient, balanced and individually rational or monitoring to prevent misrepresentation.

Fourthly, the *horizontal equity-based* transfer scheme guarantees that every country (either pivotal or non-pivotal) receives the same final payoff. The transfer *à la Weikard* allocates transfers in a way which means that pivotal countries receive zero as a final payoff and, thus, the surplus payoff is shared only among non-pivotal countries. Here, policy makers have a trade-off if they assess the implementation of NAMAs under one of these transfer schemes, namely, simplicity and political acceptability against institutional enforceability. If policy makers look rather for simplicity and political acceptability, then they may choose the *horizontal equity-based* transfer scheme because it should be seen as more pragmatic due to the fact that each country receives the same final payoff of reducing GHG emissions. However, if the institutional enforceability of NAMAs is low then some non-pivotal countries would free-ride. On the contrary, if policy makers are more interested in the fact that NAMAs works as a "self-enforcing" agreement which reduces the transaction cost of building strong institutions, they may favor the employment of the transfer *à la Weikard*. Nevertheless, estimating the outside payoffs of countries when free-riding would not be an easy task. In addition, the political acceptability of this transfer for pivotal countries may be a problem, as these countries are the largest transfer contributors and they receive zero as their final payoff.

Finally, we show our main theoretical findings by means of an illustrative example. We find that, under some specific assumptions, the DCs undertaking a *partially supported NAMAs* is the only one which has incentives to free-ride when the *horizontal equity-based* transfer scheme is employed. This kind of country is characterized by having medium GHG emission objectives and marginal abatement costs as well as middle-to-low environmental gain from avoiding GHG emissions. This fact may suggest that if the *horizontal equity-based* transfer scheme is employed to implement NAMAs, then NAMAs may be focused, in a first instance, on DCs with the highest and lowest initial valuation (i.e., initial payoff) on the NAMAs portfolio.

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General conclusions

The current climate regime has a number of caveats. Among these caveats, I can highlight four. Firstly, the lack of explicit long-term goals which aim achieve the stabilization of GHG concentrations in the atmosphere. Secondly, insufficiently stringent targets, as the committed reduction targets are not in line with a long-term stabilization goal and the commitment period under the Kyoto protocol ends in 2012. Thirdly, a narrow geographic scope due to the fact that only a few countries have binding reduction targets and one of the major GHG emitters, the U.S, has withdrawn the agreement. Finally, the insufficient promotion and transfer of low-carbon technologies. Moreover, asymmetric information and free-riding problems aggravate international cooperation. On the one hand, there are uncertainties about the costs and benefits due to the implementation of a climate policy and in the projection of two distinct scenarios - a Business as Usual Scenario (BAU) and a counterfactual scenario. On the other hand, cooperation on GHG mitigation is plagued by free-riding, since the output of mitigation activities can be viewed as a global public good. Thus, countries would have incentives to misrepresent their costs and benefits in order to take advantage of the financial transfers and GHG reduction efforts of other countries.

Two ways of achieving early and substantial reductions of GHG emissions in a post-2012 global climate policy are by enhancing the participation of DCs with mitigation activities and by promoting technology development and transfer. This thesis focused on the study of climate policies designed to foster these two issues. Technology is undeniably important for stabilizing GHG concentrations in the atmosphere. International cooperation by sharing information, costs and efforts, might accelerate and facilitate the transition to more climate-friendly technologies. In addition, the broadening of emission reductions to DCs may also contribute to reaching the stabilization of GHG concentrations.

The main objective of this research was to identify and evaluate likely global climate policies to be implemented for the post-2012 world and which focus on technological issues and/or DCs participation in order to obtain relevant findings which may contribute to moving forward the post-2012 global climate policy. The research tasks were grouped into three stages which led to three scientific articles. Each scientific article is a chapter of the present thesis. Regardless of the fact that they were developed independently, they form three interconnected economic perspectives on post-2012 global climate policy.

The first perspective carried out a literature review of post-2012 global climate policy. It proposed three ideal approaches to tackling climate change and it showed that ideal climate policies tend to be infeasible. The second perspective was based on a global survey to stakeholders involved in climate change discussions about a post-2012 global climate policy. It helped to shed more light about the feasibility of the main policy components of a new climate agreement. The last perspective assessed the feasibility of global climate policies by modelling international cooperation on GHG mitigation. It reinforced one of the major findings of the first two parts. For instance, ideal climate policies are difficult to implement. Looking at the three economic perspectives as a whole, one main conclusion may be drawn: global climate policies are affected by trade-offs. Global climate policies which may enjoy the political acceptance of international key players are not the best approach to avoiding climate change.

In the following, the main conclusions and findings of each perspective and the interconnection among them are summarized, and also some general policy implications for the post-2012 global climate policy are drawn up. Finally, some ideas for further research are proposed.

In the **first chapter** of this research, thirteen approaches proposed by scholars for post-2012 global climate policy were studied. These approaches cover the major aspects described for technological cooperation and DCs participation. A grading system was developed to assess thirteen well-known global climate architectures proposed by scholars for the post-2012 period. The grading system was based on the use of four criteria: environmental effectiveness, cost effectiveness, distributional considerations and institutional feasibility. Furthermore, two complementary statistical methods were employed: PCA and cluster analysis, with the aim of providing better support for the findings.

The main conclusion of chapter one is that there exist trade-offs among the policy components included in the proposals. Two policy components were identified as critical for institutional feasibility: the number of policy instruments a proposal comprises and the way that the U.S. takes part in the agreement. The first principal component shows that the higher the number of policy instruments a proposal comprises, the more difficult its implementation may be. Architectures that propose a wide range of instruments in order to fulfill the criteria of environmental and cost effectiveness and distributional considerations tend to be infeasible. The second principal component shows that we may not obtain the ideal equitable climate policy architecture without worsening the other architectural dimensions. In particular, an expected meaningful effort by the U.S. may affect the environmental and institutional feasibility of a global climate policy.

Furthermore, only one proposal, the *Three-part policy* (Stavins, 2004), shows the best performance on all four criteria by attaining not only a very good for three but also a good score for the fourth. This proposal is called the "first best" option for post-2012 climate policy. It proposes indexed targets for ICs and major DCs, market-based instruments and moderate targets in the short-term in order to motivate technological change and to bring down costs over time. In addition, two other proposals obtained an evaluation of good or very good performance for the four criteria: the *International agreements on energy efficiency* (Ninomiya, 2003) and *Graduation and deepening* (Michaelowa, 2007). The *International agreements on energy efficiency* suggests a transfer of the most efficient technologies in the production processes in major-emitting industries from ICs to major DCs, technological standards for the residential and transport sector and market-based mechanisms. The *Graduation and deepening* approach includes a graduation mechanism for DCs, as their per capita emissions and per capita GDP exceed a certain threshold and also proposes the use of market-based mechanisms. These two approaches may be considered as "second best" options if an eventual negotiation and subsequent implementation based on the "first best" approach faces any unexpected contingency. A subsequent cluster analysis found that the three proposals consistently formed a stable policy group. Hence, they may all be considered as suitable candidates for post-2012 climate policy, even if they are three different approaches to tackling climate change for post-2012 global climate policy.

These three best approaches share some policy components. Firstly, they propose to agree on a long-term stabilization goal. Secondly, countries bound by the agreement may use marked-based mechanisms to lower their compliance costs. Thirdly, the current climate regime would only be broadened to major DCs. It may be possible either by accepting moderate binding commitments or the use of a graduation mechanism, or by an agreement on energy efficiency. Fourthly, these proposals have a preference for indexed reduction targets. Nevertheless, *Graduation and deepening* proposes absolute quantitative targets for Annex I countries but more flexibility on the implementation of market-based mechanisms. Finally, they are too directive about how to reduce GHG emissions since they propose clear policy components to achieve their environmental objectives and they do not include a meaningful effort by the U.S. except for the *International agreements on energy efficiency* where the U.S. plays a leadership in the RD&D of low-carbon technologies.

The results of this first part of my research led me to define, in the **second chapter**, feasible components of global climate policy for the post-2012 UNFCCC regime. To do so, 149 stakeholders from Government, Intergovernmental organizations, Academia, NGOs, Media and Business in 48 countries involved in climate change discussions were contacted by means of questionnaires. An MCA was performed on the stakeholders' responses with the aim of finding answer patterns which I associated with global climate policy scenarios. Two main conclusions were found. First, that there is no consensus among stakeholders about what the future global climate policy will look like, and secondly, that there is a contrast among some of the policy components considered by the best proposals studied in chapter one and feasible elements of likely climate policy scenarios for post-2012 climate policy.

Stakeholders believe that the design of future global climate policy is divided in three main scenarios: (i) that the world will continue more or less with the current architecture, an agreement similar to a second commitment period of the Kyoto protocol (*"Kyoto redux" scenario*); (ii) that climate change issues have to be linked to economic growth giving priority to the RD&D of low-carbon technologies (*"pro-growth" scenario*); and (iii) that the post-2012 global climate policy must focus on attracting the participation of key players that are not currently bound by the Kyoto protocol, such as the U.S. and EDC (*"outside-Kyoto" scenario*). The type of scenario they envisage for the post-2012 climate regime is largely determined by the type of commitment assumed by the stakeholders for the U.S.

The scenarios identified helped to asses the feasibility of the policy components proposed by the three best proposals obtained in chapter one. Firstly, stakeholders did not judge it feasible to include a binding long-term stabilization target at the moment the agreement entered into force. Secondly, marked-based mechanisms such as CDM projects and ETS will remain in place in order to lower the compliance costs of countries bound by the agreement. Thirdly, the new climate agreement has to guarantee the participation of major DCs, specifically China, India, Brazil, South Africa, Mexico and the Republic of Korea. To entice these countries to undertake more ambitious climate policy, stakeholders propose that the agreement must include the fostering of technology and financial transfers into these countries. Finally, the type of reduction target is closely linked to the type of country. For instance, ICs (without the U.S.), are mostly associated with binding quantified emission limitations and reduction targets, whereas the U.S. is associated with a binding reduction target (either indexed or absolute), and for which a unilateral climate policy is also considered. For major DCs the stakeholders also considered non-binding targets.

Furthermore, new policy components came into light for the first time in the study since they were not considered by any of the proposals studied in chapter one. For instance, the next global climate policy will have a short duration of only a few years (i.e., no more than 10 years), probably starting in 2013. Stakeholders provide two likely solutions to foster the RD&D of low carbon technologies: (i) a renegotiation of the intellectual property rights system with the aim of reducing the time necessary for obtaining a patent by major DCs or implementing compulsory licenses; and (ii) a reduction of tariff barriers in major DCs for these kinds of technologies.

The fostering of financial transfers to DCs may be used as an incentive to attract these countries to undertake more ambitious post-2012 climate policy. This obtained a broad consensus among the stakeholders. However, countries would take advantage of the international cooperation by misrepresenting their costs and benefits related to the implementation of climate change policies. This fact drove me to study in the **third chapter** the incentives and the nature of transfer schemes for financing mitigation actions in DCs *via* NAMAs. A game-theoretical approach was developed. NAMAs was modelled as a non-cooperative, one shot game. Three conditions for full cooperation were stated: (i) individually rational, (ii) budget-balanced, and (iii) a feasibility condition. In addition, countries' deviations from full cooperation were studied, namely, free-riding and asymmetric informational problems. It was considered that some countries may be pivotal for the agreement as without them the implementation of a global climate policy would not be possible.

The implementation of NAMAs was analyzed by means of two transfer schemes: a *horizontal equity-based* scheme where every country receives the same final payoff for taking part in the agreement, and an "optimal" transfer scheme which was called *à la Weikard*. Under the latter transfer scheme, countries receive as a final payoff their outside option payoffs (i.e., when free-riding). Though pursuing a similar objective, they differ in that the *horizontal equity-based* transfer is a pragmatic transfer in the sense that it is the simplest way to distribute the total surplus payoff. The transfer *à la Weikard* is a more highly elaborated one and it is considered as an optimal sharing rule since it minimizes the incentives of countries to free-ride (i.e., abandon the agreement). Three major conclusions arose for this last part of my research. Firstly, that "no-action" is not a credible threat for key countries as would usually be thought. Secondly, that climate institutions have to focus on monitoring both GHG reductions and financing. Finally, that there is a trade-off in the use of these two transfer schemes, namely, political acceptability against institutional enforceability.

Concerning free-riding incentives, the game-theoretical approach employed showed that NAMAs are "self-enforcing" for countries which are pivotal regardless of the transfer scheme employed. In addition, the transfer *à la Weikard* allows the implementation of a self-enforcing NAMAs coalition, also for all non-pivotal countries if the total surplus payoff covers the total outside option payoffs of these countries. Nevertheless, in this regard, the *horizontal equity-based* transfer does not avoid free-riding for non-pivotal countries with outside payoffs larger than the average initial payoffs. Nevertheless, neither transfer schemes avoid asymmetric informational problems when countries misrepresent either their mitigation costs or environmental gains from implementing NAMAs.

The *horizontal equity-based* transfer scheme may enjoy some political acceptance among, participating countries, as the distribution of total surplus following an egalitarian rule may be viewed as fair by participating countries in the agreement. However, if the institutional enforceability of NAMAs is low then some non-pivotal countries would free-ride. On the contrary, NAMAs may work as a "self-enforcing" agreement which reduces transaction costs of building strong institutions to enforce participation, if the transfer *à la Weikard* is employed. Nevertheless, estimating the outside option payoffs of countries when free-riding would be neither an easy nor a politically neutral task. In addition, pivotal countries may be against its implementation as these countries are the largest transfer contributors and they receive zero as their final payoff.

Implications for the post-2012 global climate policy

Taking into consideration the main conclusions and findings of the three economic perspectives I developed in this thesis, I can envisage some of the most important policy implications which would move forward the post-2012 global climate policy.

Firstly, from the analysis of elements included in the three best proposals out of thirteen studied in the first chapter, it can be inferred that, in general, a post-2012 global climate policy will have to include the smallest set of policy instruments to make it work, and be U.S. compatible in order to gain in feasibility. In addition, there is no doubt that Annex I countries will continue with the leadership in reducing GHG emissions. Where incentives are concerned, for Annex I countries - particularly for the U.S. - flexibility mechanisms to lower compliance costs are needed, such as CDM, ETS, JI, as well as an extension of the scope of CDM projects. Furthermore, an involvement of major DCs (i.e., EDC) with some mitigation activities either through indexed targets or a graduation mechanism would favor the participation of the U.S. Here, the transfer of the best available technologies for efficiency improvements and the creation of an international fund for RD&D would serve as incentives for the participation of these DCs.

Secondly, from the participatory approach developed in the second chapter, I can refine the results from the first step mainly on the side of feasibility of some climate policy instruments. Consequently, the most likely starting date for a new global climate agreement will be 2013; and that not only DCs do need technology transfer but also financial incentives both for mitigation and adaptation. Additionally, long-term targets for countries would not be stated at the moment this agreement enters into force. Besides, stakeholders with some experience in climate change negotiations associate the participation of the U.S. with a binding indexed target (i.e., the *"pro-growth"* scenario) to an important deployment of low-carbon technologies. Hence, the agreement would include measures such as the renegotiation of the intellectual property rights system in order to facilitate the adoption of low carbon technologies for EDC, and the reduction of tariff barriers (i.e., border taxes) for low-carbon technologies by EDC, such as quota, which would lead to an average increase of trade of some low-carbon technologies, as Annex I countries are the main producers of these kinds of technologies. One significant way for EDC to participate is by the rapid introduction and use of low-carbon technologies and not by the implementation of a binding indexed target as suggested by the best proposals of chapter one.

Finally, from the game-theoretical approach developed in the third chapter, I can state that NAMAs offer a new opportunity of reducing GHG in DCs. Furthermore, they will constitute one of the principal channels for the flow of financial resources from Annex I countries into DCs in the post-2012 global climate policy. There, the design of the transfer schemes for that will play a crucial role in creating the necessary incentives for the participation of countries. It is possible to have transfer schemes which are individually rational and budget-balanced. However, depending on the type of transfer scheme, its efficiency at avoiding free-riding may vary. If free-riding is the priority for policy makers, a transfer scheme such as *à la Weikard* allows the formation of self-enforcing coalitions if the surplus of participating countries covers their outside option payoffs. Nevertheless, if equity concerns prevail, horizontal transfer schemes would play a key role in the post-2012 global climate policy, although additional incentives are needed to avoid free-riding for some kind of countries. Unfortunately, transfer schemes which are individually rational, budget-balanced and provide the NAMAs in an efficient way fail to avoid asymmetric information. For this reason, the UNFCCC will have to center its attention on developing strong institutions for MRV, both to corroborate financing and GHG reduction efforts.

Further research

From the above outlook, four main strands of further research could be pursued.

Firstly, the first two chapters found that the way in which the U.S. takes part in the post-2012 agreement affects the features of the post-2012 global climate policy. In this research, only the role at the international level of the U.S. is considered. Nevertheless, further research is needed to elucidate how U.S. internal issues - such as domestic climate legislation - would influence the design of global climate agreements.

Secondly, this research mainly focused on the study of global climate policies centered on GHG mitigation. However, the development of a more integral approach involving both mitigation and adaptation would offer a more comprehensive picture including the proposal of solutions for enhancing international cooperation on climate change.

Thirdly, even if this research takes into consideration the role of pivotal countries in the design of NAMAs, more research has to be undertaken to really elucidate the role of these countries in global climate agreements.

Finally, the finding of adequate transfer schemes for the provision of a global public good still constitutes a challenge for economists. As shown in this thesis, efficient transfer schemes for the provision of a public good fail to avoid misrepresentation of countries and vice versa.

Appendix A

Appendix to Chapter 1

A.1 Brief description of the technology-oriented proposals

A) *Technology Backstop Protocol (Edmonds and Wise, 1998)*

This approach is based basically on technology standards to control carbon emissions. The authors think that it might serve as "backstop" regulation of fossil energy use. There are two stages in the protocol. In the first stage, any new fossil fuel electric power capacity installed after 2020 in an Annex I nation must scrub and dispose of the carbon from its exhaust stream; and any new synthetic fuel capacity must capture and dispose of carbon released in the conversion process. In the second stage, starting in 2050, all new fossil fuel refining capacities in Annex I nations must remove and sequester carbon from fuels; and imports of refined fossil fuel products are linearly phased out over the following 45 years. This approach is examined under two alternative reference energy futures, one dominated by coal, the Coal Bridge to the Future - Energy Alternative (CBF), and another dominated by unconventional oil and gas, The Oil and Gas forever - Energy Alternative. There exists a graduation mechanism for DCs participation based on per capita income. For each stage, DCs must undertake the same obligations as ICs when they reach the level of per capita income that prevailed in Annex I nations when they undertook their obligations. Finally, a similar mechanism to the current JI projects under the Kyoto protocol would be considered to reduce the cost of implementing the technological targets by the binding nations.

B) *Portfolio approach (Benedick, 2001)*

This proposal suggests a strategy which could be followed by the U.S. in order to become a serious negotiating partner in a future climate change agreement. Four elements are needed for an effective post-Kyoto U.S. plan action: (i) to start reducing emissions, a modest initial domestic ETS would send a message to industry and to other nations that the U.S. is taking the problem seriously; (ii) to invest in a technological revolution, hence the U.S. could lead ICs to commit themselves to raising their grossly inadequate level of research by a significant and annually rising percentage of civilian research programs; (iii) to adopt technology-based objectives, for example new plants and refineries built after a certain date could be required either to use renewable energy or to capture and dispose of carbon byproducts; and (iv) to accelerate technology transfer and JI, governments and industry in the ICs should become serious transferring new-related technologies to the developing world. In addition, the proposal includes JI, CDM projects and a tax for funding new technology research.

C) *Research and Development approach (Barrett, 2003)*

This approach proposes five main elements: (i) an RD&D protocol to "push" the development of new technologies; (ii) protocols establishing technology standards, in order to provide a "pull" incentive to commercialize new, low-emitting technologies; (iii) a multilateral fund to help spread new technologies to DCs; (iv) a short-term system of pledge-and-review; and (v) a protocol for adaptation assistance. It is proposed to start with Europe, Japan and the U.S., at least at the beginning. The timescale of this approach would be long enough for technology transition.

D) *International agreements on energy efficiency (Ninomiya, 2003)*

This architecture proposes to negotiate an international agreement on energy efficiency addressing the production processes in major-emitting industries through transferring existing technologies from the higher efficiency countries to the lower ones. Such an agreement would complement the Kyoto Protocol and would aim at participation by the United States and major DCs. In addition, the nations should develop international standards for appliance efficiency in the residential and transportation sectors and the improvements would be measured by the OECD. Ninomiya (2003) argues that improvements on energy efficiency provide a self-incentive to take action. Moreover, the establishment of a global RD&D fund would create additional incentives for the participating countries. These agreements could be compatible with the CDM/JI projects under the existing Kyoto regime.

E) *Technology prizes (Newell and Wilson, 2005)*

This proposal focuses on inducement prizes at the middle stages of the technological change process: RD&D. Technology prizes have a role to play in the portfolio of inducement mechanisms available to spur climate change-related technological advances. The prizes' design can be divided into three categories: firstly the technological target to slow or stop the rise of net GHG emissions in order to mitigate the risk of global climate change; secondly, the size and nature of the prize, where organizers must determine the magnitude of the financial award first; and thirdly, the method of selecting the winner either by the *first-past-the-post*[1] or by *contest*[2]. It would be more reasonable that each climate technology prize focus on one research area at a time.

F) *Orchestra of Treaties (Sugiyama and Sinton, 2005)*

This proposal consists of four building blocks. Three groups are built outside the UNFCCC system: (i) a Group of Emission Markets (GEM) built up from separate domestic markets without imposing international emission targets in order to realize low cost mitigation opportunities; (ii) a Zero Emission Technology Treaty to foster long-term technological change; (iii) a Climate-wise Development Treaty (CDT) addressing the concerns of DCs such as promotion of development, technology transfers, adaptation and mitigation. The role of UNFCCC is reduced to serve as an information exchange arena, target funding mechanism and political focal point; for example, it would lead some protocols and mechanisms, an emission monitoring protocol, an information exchange mechanism and targeted funding addressed to capacity building for least DCs and small island states.

A.2 Brief description of proposals for developing country participation

G) *Multi-dimensional structure (METI, 2003)*

In this approach, the core of commitments are specific actions and technology development. National targets are considered as complementary. The architecture would start with the top fifteen emitters (Eropean Union is counted as one country) who seek an agreement among themselves. Commitments include measures that lead to emissions limitations in DCs. The proposal includes, on the one hand, intergovernmental cooperation where devel-

[1]The prize is awarded to the first competitor to achieve the stipulated goal.

[2]Contestants have a specific amount of time to develop a technology that will be judged on a given set of criteria.

oped countries should further strengthen their cooperation with DCs by supporting policies for energy-saving and by providing financial support; and on the other hand, a private sector cooperation by promoting private investment in energy and environmental fields trough CDM projects.[3] Furthermore, JI and emissions trading are also considered, as well as measures that bring about fundamental emission reduction such as setting trans-boundary and sectoral targets on, for example, energy efficiency standards. In this way, the development of new energy systems would be undertaken mainly by ICs. The proposal includes the establishment of international RD&D funds for addressing climate change and it specifies 2013-2030 as next period of commitments. A periodical pledge-and-review system is considered as well.

H) *Bottom-up approach (Reinstein, 2004)*

This approach suggests the negotiation of a package of multi-component commitments by each country based on national circumstances and negotiated from the bottom up, as in a multilateral trade agreement. Short-term commitments begin the process and send a political signal about the possible direction of the agreement. Commitments to RD&D would focus on finding solutions to the longer-term issues and needs of sustainable economic and social development and they would relate both mitigation and adaptation efforts. In addition, a commitment to a package of policies and measures would be accompanied by a projection of the emission limitation expected to result from the measures. ICs would commit to enhance climate research and public education and awareness and emission reductions would be carried out through projects in other countries by CDM or JI projects.

I) *Common but differentiated convergence (Höhne et al., 2006)*

This proposal is based on the *Contraction and Convergence* approach of Meyer (2005). Under the *Common but differentiated convergence* approach countries are grouped into three categories: ICs which would reduce their emissions until they converge within a convergence period to a low level (e.g. 2.9 tCO_2 eq/cap from 2010-2050, although from 2012

[3] METI (2003) asks for a fundamental reform of the current conception of CDM projects as follows: (i) encourage unilateral CDM projects, i.e., GHG reduction carried out by a DCs within its borders; (ii) approve projects which introduce energy-saving technologies or efficiency standards earlier agreed; (iii) introduce CER acquisition as mandatory for ICs and at the same time to establish a limit on the amount of CER to acquire for a ICs.

as well). The other two remaining groups, Advanced Developing Countries (moderate-per capita emissions) and Least Developed Countries (low per capita emissions) are allowed to converge to the same level also within the same period (common convergence), but the reduction starts when their per capita emissions reach a certain percentage threshold of the global average (the differentiated part, e.g. a threshold of 10% below world average). Until then, they take part in the CDM or they may voluntarily take on "no-lose" reduction targets allowing them to sell emission allowances if their real emissions are below the target. Least Developed Countries are the last to converge.

J) *Formulas for emission targets (Frankel, 2007)*

With the aim of establishing equal per capita emission targets for the long-term (after 2100), the proposal sets country-level quantitative targets through formulas based on income, population, 1990 emissions, resource endowments, and other variables. Frankel (2007) considers a century-long horizon with targets being fixed for a decade at a time. In the short-term, these formulas would yield progressive targets and converge to equal per capita emission targets in the long-term. The proposal includes international ETS and sufficient commitments for DCs to ensure that they would enjoy net benefits from near-term participation in the global climate policy regime. Emission targets for DCs could also be indexed to their economic growth.

K) *Graduation and deepening (Michaelowa, 2007)*

This proposal orients the current climate regime towards strong emission reduction commitments by deepening and expanding quantitative emission targets. It advocates a global long-term atmospheric stabilization goal of 550 ppm CO_2 to be achieved through quantitative, legally binding, country-specific targets. Countries with emission commitments could engage in international ETS. DCs would take on emissions targets through a graduation mechanism: as their per capita emissions and per capita gross domestic product exceed certain thresholds, they would have to take on more and more ambitious targets. Upon graduating to a higher threshold, a country's target would tighten to match that of countries with similar emissions and income profiles.

L) *Pledge-and-review (Pizer, 2007)*

This approach calls for the largest emitters to pledge specific actions and policy commitments based on strong domestic political support, which can take any form (such as ETS, taxes, or a suite of technology standards). These commitments would be non-binding, and there would be no minimum commitment necessary to participate. Countries would link their activities, such as among European Union member states. Rolling five-year reviews of national policies, patterned on the OECD countries' review process, would serve as the means for evaluating effort. These reviews would focus on emission mitigation, technology development, and DCs involvement. Every five years, a major evaluation of progress would be undertaken and a new round of commitments would be put forward.

M) *Three-part policy architecture (Stavins, 2004)*

This approach proposes three main components: (i) global participation, i.e. major ICs and key DCs through the use of economic trigger mechanisms such as *growth targets*; (ii) long-term targets in which two elements are needed: first, firm but moderate targets in the short-term and secondly, the flexible but more stringent targets for the long-term in order to motivate technological change and to bring down costs over time; and (iii) market-based policy instruments such as ETS, carbon taxes, or a mixture of both.

A.3 Information considered in the grading

Table A.1: Elements from the thirteen global climate policy architectures considered in the grading

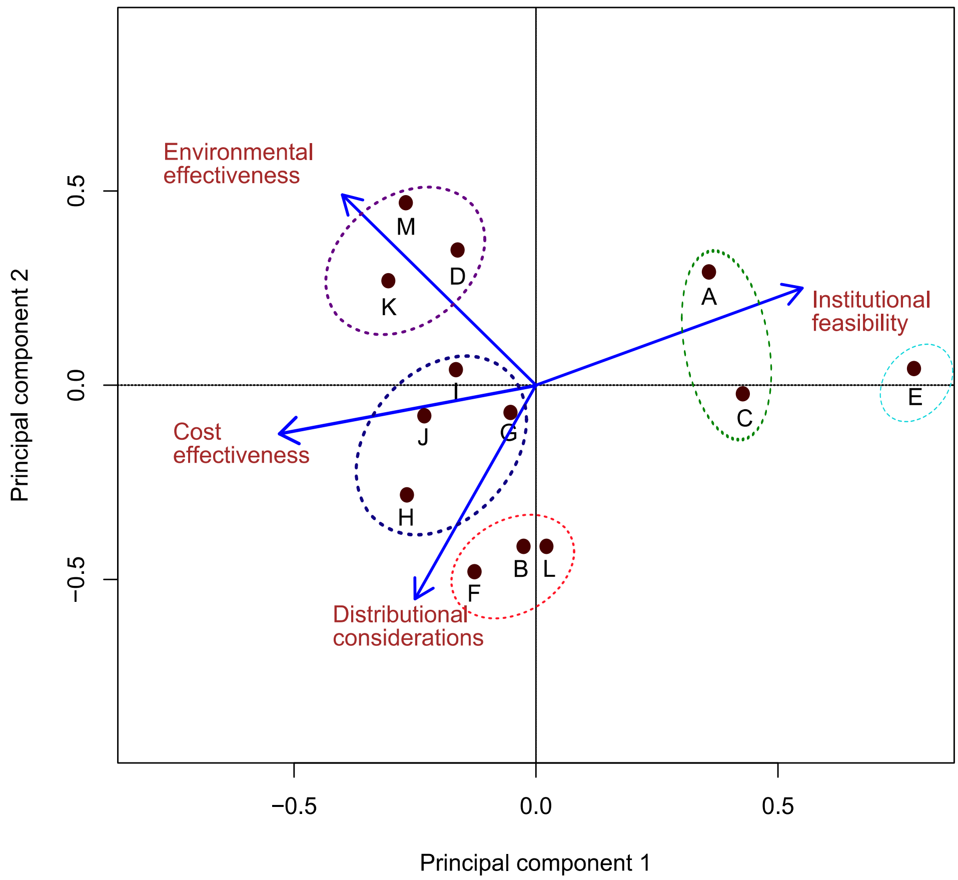
Proposal	Environmental effectiveness	Cost effectiveness	Distributional considerations	Institutional feasibility
A)Technology backstop protocol (Edmonds and Wise, 1998)	Very good: (+) the authors prove that under the alternative scenario CBF, the GHG concentrations stabilize at approximately 510 ppm in the atmosphere by the end of the century	Poor: (-) based on technology standards with an unclear flexibility mechanism	Medium: (+) annex I countries continue to be the leaders in cutting emissions (+) graduation mechanism for DCs (-) no meaningful effort by the U.S. (-) no assistance to DCs in dealing with climate change (-) no additional assistance to DCs	Good: (+) compatible with the current climate regime (+) high willingness of the U.S. to cooperate and some of the more rapidly growing economies (-) it is not addressed how to overcome the existing barriers for technology deployment and diffusion
B) Portfolio approach (Benedick, 2001)	Medium: (+) policies and measures conceived to stimulate reductions by the 21 nations which account for 80% of global emissions, and the adoption of long-term technological strategy, as well as the acceleration of technology transfer (-) fails in not setting precise reduction targets either for short or long-term. In addition, it focuses only on bigger emitters, which allows emission leakage	Good: (+) the inclusion of 10 major DCs as well as JI and CDM projects reduces the costs (-) adoption of technology-standards objectives tends to lead to non-cost-effective outcomes. An expected rising of RD&D costs	Good: (+) conceived to reach a meaningful leadership of the U.S. to reduce emissions (+) ICs provide financial resources to DCs in dealing with climate change (+) ICs continue with the leadership tackling climate change (+) major emitters from DCs constraint emissions (-) no additional assistance to DCs	Poor: (-) would not attain the acceptance of major international players because asks the U.S. to take the leadership in tackling climate change in the short term and ICs are asked for significant financial transfers towards DCs (-) would require a new international negotiation framework
C) Research and development approach (Barrett, 2003)	Medium: (+) strong enforcements on RD&D of climate-technologies and the implementation of rigorous protocols for technology standards which include strict trade restriction for technologies that fail to meet the standard (-) It does not provide a base for the needed stabilization of GHG concentrations in the atmosphere; it should imply emissions leakage	Poor: (-) no flexibility mechanisms are considered to lower costs (-) high costs for countries engaged to finance the RD&D protocol	Good: (+) the U.S. will have a meaningful participation financing the RD&D protocol (+) continued leadership of annex I countries (+) ICs assist DCs in adaptation and DCs do not pay all their costs (-) no commitments for DCs (-) no additional assistance to DCs	Good: (+) would complement the current climate regime (+) high willingness of the U.S. to cooperate and some of the more rapidly growing economies (-) the negotiation for establishing standards and rules would lengthly extends the negotiation process

Proposal	Environmental effectiveness	Cost effectiveness	Distributional considerations	Institutional feasibility
D) International agreements on energy efficiency (Ninomiya, 2003)	Good: (+) focuses on energy efficiency levels in the industrial sector among major countries through the deployment of the best existing energy saving technologies and the implementation of international standards for energy efficiency levels in the residential and transport sectors (-) Neither short nor long-term targets are set, which makes attaining the ultimate objective of the UNFCCC uncertain	Very good: (+) proposes abate in DCs where marginal costs are lower (+) compatible with the CDM/JI projects (+) indexed reductions targets	Good: (+) the U.S. play a key role in the agreement (+) ICs continue the leadership reducing emissions and transferring technology (+) take part major DCs (+) the RD&D fund would help DCs countries dealing with Climate Change (-) no additional assistance to DCs	Very good: (+) compatible with the current climate regime (+) OECD countries and the other participants already take part in similar programs, then it would have high chances of acceptability and implementation
E) Technology prizes (Newell and Wilson, 2005)	Poor: (-) There is uncertainty about GHG emissions reduction for short and long-term since it is difficult to measure how technology inducement prizes and later technology deployment are implemented.	Medium: (+) may reduce the influence of lobbying on politics for research funding allocation, and improve the RD&D assignment by avoiding the principal-agent's problems related to this (-) it might imply an increase of transaction costs by a duplication of innovation effort	does not address distributional considerations at all	Very good: (+) useful complement to RD&D under the current climate regime and compatible with the international property right system (+) would be easy to implement since it can be based on pre-existing research support programs (+) technology prizes would gain the acceptance of all major players
F) Orchestra of Treaties (Sugiyama and Sinton, 2005)	Medium: (+) it would to some extent reduce GHG emissions by the implementation of national ETS by ICs (-) ETS without internationally imposed quota allocations, and long-term climate change issues only focus on technological change	Good: (+) the group of emissions markets helps in the implementation of low-cost options; costs of long-term technological change decrease; a carbon price convergence (-) solutions proposed to avoid carbon price volatility would increase the transaction costs	Very good: (+) the U.S. could be the core of the GEM (+) continued leadership by developed countries in long-term technological development and short term emissions cuts (+) expected a meaningful participation of DCs (+) CDT address DCs concerns related to the promotion of development, technology transfers, adaptation and mitigation (+) ICs help DCs by supporting development assistance programs	Poor: (-) mains elements are negotiated outside the UNFCCC system to avoid the impasse of Kyoto Protocol resulting in lengthy negotiations

Proposal	Environmental effectiveness	Cost effectiveness	Distributional considerations	Institutional feasibility
G) Multi-dimensional structure (METI, 2003)	Medium: (+) promotion of cooperation for energy-saving measures in DCs and reinforcing capacity building, assistance in policy making, joint RD&D and sectoral technology cooperation, in addition to the development and diffusion of innovative technologies (-) the fact that commitments are focused on cooperation with DCs and technology development instead of setting quantitative targets makes attaining the ultimate objective of the UNFCCC uncertain. The participation restricted to major DCs does not avoid emissions leakage	Good: (+) allows reduction of mitigation costs via the inclusion of CER earned by CDM and JI projects; the reform of the CDM decreases compliance cost (-) the CER system has two main constraints: (i) certain level of CER acquisition is mandatory to ICs but (ii) the amount of CER is limited	Very good: (+) continued leadership by developed countries (+) inclusion of some DCs (+) the U.S. would play a leading role in terms of technology development (+) ICs support policy formulation for energy-savings and RD&D funds (-) no additional assistance to DCs	Good: (+) compatible with the current climate regime (+) major DCs and the U.S. would favor agreements based on technology issues (-) the proposed CDM reform would considerably extend the negotiation process
H) Bottom-up approach (Reinstein, 2004)	Good: (+) implementation of the ambitious package of commitments by all countries, depending on their own national circumstances, rather than only reduction targets (-) some kind of policies and measures proposed (e.g. climate RD&D and more public education and awareness) are not in line with the UNFCCC stabilization target	Very good: (+) completely flexible since each country chooses the cheapest path to reduce emissions	Good: (+) continued leadership of ICs (+) ICs take assistance to DCs in adaptation concerns (+) inclusion of DCs with emission limitations (+) ICs support capacity building, financing RD&D, etc (-) no meaningful effort by the U.S.	Poor: (-) would require long process of negotiation to reach an agreement (-) would require a new international negotiation framework
I) Common but differentiated convergence (Höhne et al., 2006)	Very good: (+) Designed with the aim to stabilize concentrations at 550 ppm by the end of the century	Good: (+) includes a global emission market for countries which pass a threshold and the remaining countries take part through CDM projects (-) for short-term does not include the participation in full of some DCs with low marginal abatement costs (e.g. China and India)	Very good: (+) ICs countries take action from the beginning (+) meaningful effort by the U.S (+) graduation mechanism for DCs (++) DCs receives large resource transfers which could be used both for adaptation measures and economic development	Medium: (+) compatible with the current climate regime (+) differentiated reduction targets makes this approach globally attractive (-) the U.S. would be reluctant to the use of an equal per-capita distribution as burden sharing rule for GHG reductions
J) Formulas for emission targets (Frankel, 2007)	Good: (+) ICs participation and a more comprehensive expected participation of DCs with reduction targets allows emission reductions, at least, below the BAU (-) it does not ensure the achievement of a long-term stabilization target much later than the end of this century	Very good: (+) comprises a ETS with a safety valve and *side payments* to encourage participation (+) no major costs for new participants since their targets for the first period are close to their estimated BAU and existing members gain by buying cheap permits from them	Good: (+) continued leadership by ICs, excepted Australia (+) some DCs constraint emissions (++) DCs have access to financial resources which could be used both to deal with climate change and other issues (-) the U.S. is treated as a DCs in the near term	Medium: (+) compatible with the current climate regime (-) the U.S. would not favor of a *side payment* system to DCs

Proposal	Environmental effectiveness	Cost effectiveness	Distributional considerations	Institutional feasibility
K) Graduation and deepening (Michaelowa, 2007)	Very good: (+) The approach includes several measures and targets that reach the stabilization at 550 ppm by the end of the century	Very good: (+) comprises ETS and JI projects (+) the scope of CDM projects is enlarged with the inclusion of other sectors (+) DCs emitters with targets may choose between an *ex ante* intensity target or use countrywide CDM	Good: (+) continued leadership by ICs (+) graduation index to guarantee DCs participation (+) DCs obtain benefits for participation in the reformed CDM projects (-) no meaningful participation of the U.S. (-) no additional assistance to DCs	Good: (+) compatible with the current climate regime (+) the inclusion of the sources and sinks could be attractive to the U.S. and other countries with large geological reservoirs, vegetation and marine areas (-) difficult to negotiate the inclusion of new sectors in the scope of GHG mitigation and for CDM projects before the period 2013-2017
L) Pledge-and-review (Pizer, 2007)	Medium: (+) expected engagement of major DCs on as many levels as possible and by opening the scope of commitments (e.g. intensity targets, carbon prices, standards and RD&D) (-) Non-binding commitments translate on uncertainty on GHG emission reduction; it does not avoid emissions leakage	Good: (+) bottom-up policies provide greater protection against excessive costs; includes CDM and JI projects (-) the author is against to the formalization of mechanisms to equalize marginal costs such as international ETS or a tax rate on GHG emissions	Good: (++) major economies and emitters take part (i.e. ICs and DCs) (+) DCs activities are encouraged by project-based crediting, linking climate policy to trade and development and security (-) no meaningful participation of the U.S. (-) no additional assistance to DCs	Poor: (-) would require long process of negotiation to reach an agreement (-) would require a new international negotiation framework
M) Three-part policy architecture (Stavins, 2004)	Very good: (+) An expected broad participation and focus on a long-term target at 550 ppm for the end of the century	Very good: (+) the inclusion of DCs provides opportunities for low-cost emissions reductions activities (+) focused on market-based policy instruments	Good: (+) continued leadership by ICs (+) key DCs take part (+) DCs participate without incurring prohibitive costs (-) no meaningful participation of the U.S. (-) no additional assistance to DCs	Very good: (+) compatible with the current climate regime (+) the targeted emissions to per capita income described to DCs would give them incentive to accept a binding reduction target (+) would be easy to negotiate and implement

A.4 The PCA map



A) Technology backstop protocol
B) Portfolio approach
C) Research and development approach
D) International agreement on energy efficiency
E) Technology prizes
F) Orchestra of Treaties
G) Multi-dimensional structure
H) Bottom-up approach
I) Common but differentiated convergence
J) Formulas for emission targets
K) Graduation and deepening
L) Pledge and review
M) Three part policy

Figure A.1: Projection of the groups of proposals on the PCA map

Appendix B

Appendix to Chapter 2

B.1 Stakeholders' affiliation

List of stakeholders' affiliation[1]

1. Associacao de Protecao a Ecossistemas Costeiros (APREC), Brazil
2. Association for Corporate Environmental Issues (OBU)
3. Bahamas Department of Meteorology
4. British Consulate General Cape Town
5. CEDAN, Mexico
6. Center for International Climate and Environmental Research, Oslo
7. Centre for European Policy Studies
8. Centre for Socio-Economic Development (CSEND)
9. Climate Action Network
10. Climate Cent Foundation
11. Climate Change and Environmental Risks
12. Climate Consultant
13. Climate Institute
14. Climatenet
15. Conservation Agriculture Capacitator, South Africa
16. Department of Parliamentary Services, Australia
17. Deputy Project Manager - Global Alliance for Climate Justice
18. Earth Advantage Institute
19. Earth Future

[1] As the survey was based on an anonymous principle, some stakeholders did not provide their affiliations. In addition, sometimes more than one stakeholder is affiliated to the same organization. Stakeholders' answers were considered exclusively as their personal opinions, they were not taken as the positions of their organizations.

20. Ecosystem Marketplace
21. Eneco
22. Energy Research Centre of the Netherlands
23. Environment, Health & Safety - Trakhees, Dubai
24. Environmental Energy Consultants Ltd Fiji
25. Environmental Management & Social Development Group, India
26. Escuela Superior del Litoral, Spain
27. European Commission, DG Research, Directorate Environment, Unit I5
28. EUtech Energy and Management GmbH
29. Facultés Universitaires Saint-Louis à Bruxelles
30. Fibertel
31. Fletcher School of Law and Diplomacy, Columbia University
32. Fondazione Eni Enrico Mattei (FEEM)
33. Free University of Berlin
34. Fridtjof Nansen Institute, Norway
35. George Mason University
36. GHG Certification Center, Environmental Management Corporation
37. Gujarat National Law University
38. Hessisches Landesamt für Umwelt und Geologie
39. Holland & Hart LLP
40. Humboldt State University, USA
41. IDEAcarbon

42. Indian Institute of Management
43. Indonesia's National Council on Climate Change
44. Intercooperation
45. Institute of Environmental Protection, Warszawa
46. International Centre for Trade and Sustainable Development (ICSTD)
47. International Development Research Centre, Singapore
48. International Emissions Trading Association (IETA)
49. International Energy Agency, Directorate of Sustainable Energy Policy and Technology
50. International Environmental Law Research Centre (IELRC)
51. International Institute for Applied Systems Analysis (IIASA)
52. International Institute for Sustainable Development (IISD)
53. International Risk Governance Council
54. Intituto Nacional de Ecología, Mexico
55. Kenya Agricultural Research Institute
56. KFW Bankengruppe, Frankfurt
57. London School of Economics
58. Mecon Limited
59. Ministry of Energy, Kuwait
60. Ministry of Environment, Czech Republic
61. Ministry of Environment, Slovakia
62. Ministry of Environment, Bulgaria

63. Myclimate
64. National and Kapodistrian University of Athens
65. Natural Sciences Sector, UNESCO
66. Nature Canada
67. NOE21
68. P.Eng., Canada
69. Pace Law School, New York
70. Point Carbon
71. ProClim
72. PRODENA, Bolivia
73. Public Services International
74. Qatar Academy
75. Réseau Action Climat-France (RAC)
76. REME-EPFL
77. Renmin University
78. Research Council of Norway
79. School of Geography and the Environment, University of Oxford
80. Secretaria de Ambiente y Desarrollo Sustentable, Argentina
81. S.J. secretary of JESAM, Kenya
82. State University of Campinas
83. SWECO
84. Swiss Federal Office for the Environment

85. SWP-Germany
86. Symbiotic Strategies LLC, USA
87. The Center for Clean Air Policy
88. The World Business Council for Sustainable Development
89. Tricorona
90. TUV Rheinland Japan Ltd.
91. TÜV, Industry Service
92. Uganda Coalition for Sustainable Development (UCSD)
93. UNFCCC
94. UNDP, Africa Adaptation Programme
95. UNEP DTIE-Energy Branch
96. UNEP, Division of GEF Coordination
97. Universität Potsdam
98. Universiti Teknologi PETRONAS
99. University of British Columbia
100. University of Chittagong
101. University of Natural Resources and Applied Life Sciences, Vienna
102. University of Venice
103. University of Zurich
104. Wiley Rein LLP

B.2 The survey-questionnaire

Survey on feasible climate policy elements for the next commitment period (post-2012)

Introduction and Goal

In this questionnaire, I would like to ask your opinion regarding the **feasibility** of different policy instruments and targets to be included in the next commitment period (post-2012 of global climate policy). Your answers will help in a research work on identifying feasible candidate approaches for the next commitment period. All information given by you will remain confidential and it will be used solely for scientific purposes. Moreover, this information will not be shared with third parties. The answers to the questionnaire will be considered exclusively as personal opinions and they will not be taken as the position of your organization.

I would like thank you in advance for your cooperation.
Best Regards,
Ronal C. Gainza
PhD Student

Please, select **a single answer per question** unless stated otherwise (i.e. as in questions *8.2*, *9*, *10* and *12*).

1) Country (i.e. country where working): ☐

2) Do you work **mainly** for what kind of organization?

☐ for a governmental institution (e.g. ministry, governmental agencies, parliament, national commissions, etc.)
☐ for a non-governmental organization, area: ☐
☐ for representatives bodies of the UN system or intergovernmental organizations, (e.g. UNFCCC, UNEP, GEF, WMO, IPCC, OECD, IAEA, WTO, WB)
☐ for a Research and Academic Institution, field: ☐
☐ other, please specify: ☐

3) Do you consider that you have experience in the negotiation of climate change policies? (i.e. participation in different COPs and other meetings under the UNFCCC and the Kyoto protocol mandates, this also includes a position as *observer*)

☐ Yes, or ☐ No.

4) In your opinion, what will be the most likely starting date for the next commitment period?

Year: ☐ (e.g. at the beginning of 2013 if there is not a gap with the commitment period agreed under the Kyoto Protocol)

5) What should be the duration, in years, of this new commitment period?

Number of years: ☐ (e.g. duration of the commitment period under Kyoto protocol is 5 years, from 2008 to 2012)

6) Annex B participation. How Annex B countries (excluding the U.S) will participate in the next commitment period?

☐ accepting a **binding** absolute quantitative target (as under the Kyoto protocol) or,
☐ accepting a **binding** indexed target (e.g. ton of CO_2 per dollar of GDP, per capita emission) or,
☐ other, please specify: ☐

7) The U.S. participation.

7.1.) Target. How the U.S. will participate in the next commitment period?

☐ accepting a **binding** absolute quantitative target (as it was proposed under the Kyoto Protocol) or,
☐ accepting a **binding** indexed target (e.g. ton of CO_2 per dollar of GDP, per capita emission) or,
☐ not accepting any binding target but with a meaningful domestic climate policy, or
☐ other, please specify: ☐

7.2.) Incentives for the U.S. participation. What could be the main incentive that will lead to a **binding** engagement of the U.S. in the next commitment period?

☐ national political reasons (i.e. changing priorities of the new administration, the power lobby's pressure on the government) or
☐ international political reasons (i.e., the international pressure) or,
☐ availability of the carbon markets to lower greenhouse gases reduction costs (e.g. emission trading systems, CDM and JI projects, developing and selling low-carbon technologies)
☐ other, please specify: ☐

8) Emerging Economies.

8.1.) Among the developing countries, **s**ome Emerging Economies such as China, India, Brazil, Republic of Korea, South Africa and Mexico are asked to play a more important role in the next commitment period. How these Emerging Economies should participate in the next commitment period?

☐ accepting a **binding** absolute quantitative reduction target (similar to those currently accepted by Annex B countries) or,
☐ accepting a binding indexed target (i.e. ton of CO2 per dollar of GDP, per capita emission, etc.) or,
☐ accepting a **non-binding** quantitative reduction target with benefit from markets mechanisms (e.g. selling surplus allowances when their emissions are less that their assigned amount, but without penalty in case of no compliance) or,
☐ other, please specify: ☐

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8.2) Incentives for participation of Emerging Economies in the next commitment period. What kind of actions should be carried out by developed countries to attract the Emerging Economies to take more ambitious climate policy action in the next commitment period? **(Multiple answers are possible)**

☐ fostering the transfer of low-carbon technologies towards these countries,
☐ by applying political and/or economic coercion (i.e. developed countries increase tariffs and non-tariffs barriers for carbon intense products, climate negotiation is linked to other international political matters)
☐ the use of financial incentives (i.e. linking climate change to priority issues of Emerging Economies, for instance poverty reduction)
☐ other(s), please specify: ☐

9) Which, among the following elements, will be implemented under the next commitment period in order to enhance **Technology development and sharing** of **low-carbon technologies**? **(Multiple answers are possible)**

☐ an official agreement on the promotion of research, development, demonstration and deployment of these technologies (R&D)
☐ voluntary technology agreements on R&D (i.e. bilateral and multilateral cooperation channels)
☐ an official agreement on the adoption of some technology standards at the international level
☐ the promotion of technology deployment by changing rules of the current intellectual property right system (i.e. compulsory license or reducing the time necessary for obtaining a patent or creating an international fund to buy patents, among others)
☐ reduction of tariff barriers in developing countries for low-carbon technologies
☐ other(s), please specify: ☐

10) What kind of **flexibility mechanisms** will be included in the next commitment period to lower the compliance cost reducing greenhouse gases emissions? **(Multiple answers are possible)**

☐ emission trading systems, ☐ CDM projects, ☐ JI projects), ☐ other(s), please specify: ☐

11) How will **adaptation** concerns be handled in the next commitment period?
(Multiple answers are possible)

☐ getting a part of revenues from current mechanisms such as JI and Emission Trading Systems (similar to the 2% taken from the CDM projects, as it is now implemented),
☐ implementing a global adaptation levy (i.e. taxing fossils fuels)
☐ using other international funds. Please specify: ☐
☐ linking adaptation to other fields (i.e. development cooperation)
☐ other(s), please specify: ☐

12) Targets beyond the next commitment period (until 2030). It is argued that avoiding the risk of dangerous climate change requires that global greenhouse gases emissions will have to be reduced drastically. In this respect, the *OECD environmental outlook to 2030* assesses some policy scenarios. Which of the following do you consider as the most viable *OECD's* target from a political point of view for 2030? Consider that the baseline is the current global climate policy. (Hint: to answer this question, please remember your answers to questions 6-8).

Change in global GHG emissions relative to 2000

	Emissions in 2030 (%)	**Description**
☐	+ 52:	No further actions are taken (baseline).
☐	+ 34:	OECD countries immediately implement further reduction targets and the rest of the world will continue with the baseline emissions.
☐	+ 23	All countries implement further reductions from 2020.
☐	+ 20:	OECD countries immediately implement further reduction targets; Brazil, China, India and Russia implement them from 2020 and the rest of the world from 2030.
☐	+ 7:	All countries immediately implement further reduction targets.

13) Your personal views.
13.1.) In few words, which are the most controversial issues in the ongoing climate change negotiation process? (e.g. setting GHG reduction targets and burden sharing rules, reaching the participation of the U.S. and Emerging Economies with targets)

☐

13.2.) Briefly, what could be the ideal solution(s) for the issues that you mentioned in 13.1?

☐

B.3 Active variables

Table B.1: Statistical summary of the MCA method: active variables

Variable	Response category	Axes contribution "x-axis"	Axes contribution "y-axis"	Absolute weight[a]
Starting date	2013	0.3	0.4	93
	2014 or 2015	1.2	1.4	26
Duration	5 years	0.6	5.1	40
	6 to 9 years	0.4	3.7	65
Global GHG emission target for 2030 relative to 2000 emissions	+20%	2.6	0.0	65
	+23%	1.2	0.1	26
	+34%	3.2	0.0	15
Annex B's target	Binding absolute quantitative target	0.3	5.2	75
	Binding indexed target	0.5	9.7	39
U.S.' target	Binding absolute quantitative target	0.6	3.9	70
	Binding indexed target	1.4	4.0	20
	Unilateral climate policy	4.2	1.7	31
EDC's target	Binding absolute quantitative target	2.5	0.8	21
	Binding indexed target	0.1	0.1	43
	Non-binding quantitative reduction target	0.5	0.1	49
Flexibility Mechanisms	JI projects	2.2	0.2	67
	CDM projects	0.5	0.4	101
	Reform current flexibility mechanisms	1.2	0.4	21
	ETS	0.8	0.4	102
Incentives for EDC	Financial incentives	1.5	0.0	96
	Political and/or economic coercion	5.9	0.6	26
	Technology transfer	0.9	1.0	102
Incentives for the U.S.	Attractiveness of the carbon market	3.3	0.5	27
	National political reasons	0.0	1.5	87
	International political reasons	0.0	11.5	32
Technology	Change rules of the IPR system	6.3	0.7	42
	Official agreement on RD&D	2.0	1.1	56
	Voluntary agreements on RD&D	0.0	0.6	74
	Adoption of technology standards	1.7	0.1	35
	Reduction of tariff barriers in EDC	5.9	0.8	55
Adaptation	Add other financial sources	2.1	5.4	77
	Linking adaptation to other fields	0.0	1.1	86
	Implementing a global adaptation levy	5.3	4.2	40
	Using other international funds	2.0	1.8	33

[a] The response categories of the variables: starting date, duration, global GHG emission for 2030, Annex B's target, U.S.' target, and EDC's target have to add up 123 (our total number of respondents of the survey-questionnaire). However, it is important to remember that in this study we did not employ for the MCA the active response categories which are represented by less than 10%. Thus, these are not shown in the table and they may add up to less than 123. The response categories of the variables (flexibility mechanisms, incentives for EDC, incentives for the U.S., technology, and adaptation) are converted to dummy variables for the MCA, since they are not mutually exclusive (i.e., as in the standard format questionnaire). Therefore, for each of these response categories the maximum level of their absolute weight is 123. The "no" response category choice for each dummy variable is not shown.

B.4 Supplementary variables

Table B.2: Statistical summary of the MCA method: supplementary variables

Variable	Response category	Test-value	Absolute weight[a]
Stakeholder's type	Non-governmental organizations	0.6	25
	Academia	0.8	47
	Intergovernmental organizations	1.3	9
	Business	0.7	16
	Government	0.4	24
	Media	0.6	2
Experience in climate change negotiation process	Have participated	2.1	68
	Have not participated	2.1	55
Controversial issue in the climate change negotiation process	Setting targets	0.4	97
	Technology and resource transfer	0.7	22
	Integration of climate change to trade and development	1.1	30
Solutions for setting targets	More technology and financial assistance to DCs	0.4	25
	Exhausting political negotiations	1.5	35
	Continued leadership of ICs	1.2	12
Solutions for technology and resource transfer	Reform current flexibility mechanisms	1.0	6
	Exhausting political negotiations	1.4	7
	Continued leadership of ICs	0.7	4
Solutions for the integration of climate change to trade and development	Reform current flexibility mechanisms	0.4	11
	More help to DCs	1.0	6
	Take radical measures	1.2	9

[a] The response categories of the variables: stakeholder's type and experience in climate change add up to 123. The response categories of the variable controversial issue in the climate-change negotiation process are converted to dummy variables for the MCA since they are not mutually exclusive (i.e., as in the standard format questionnaire). Therefore, for each of these response categories the maximum level of their absolute weight may be 123. The "no" response for each dummy variable is not shown. The response categories for the variables (solutions for setting targets, solutions for technology and resource transfer, and solutions for the integration of climate change to trade) should be the same as the figure of the associated controversial issue. However, not all stakeholders that have identified a controversial issue have proposed a solution for it. Thus, there is a difference in the final answers between issues and solutions. For instance, 97 stakeholders consider that the most controversial issue is that of setting targets among the different groups of countries. However, the response categories for the solution of this controversial issue add up to just 72.

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2008-2009: Teaching Assistant for the following courses at EPFL:

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2004-2006: Business School, University of Geneva, Switzerland

Internship on sustainable development and climate change at Logilab - Research laboratory on Operational Research.

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Consulting on ISO 14 001 environmental management systems for the following organizations:

- The asphalt-roofing industry "Tejas Infinitas" de Camagüey (Head of project)
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- Sugar construction business group of Camagüey (GECA)

Involved in the following environmental projects:

- Study of Air Pollution in the construction factory "Refractarios"
- Trace metal analysis in the workplace in the factory "Tejas infinitas"
- Methodology to identify and assess industrial risks for Cuban workers
- Health-care waste management system for the maternity hospital of Camagüey (Head of project)
- Environmental assessment of the gas factory "Gases Industriales" (Head of project), and the foundry of Camagüey's railways.

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